D. W. Mead

# EARTHWORK

## AND ITS COST

BY


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NEW YORK

THE ENGINEERING NEWS PUBLISHING CO.

1903

TO

HENRY S. MUNROE,

PROFESSOR OF MINING ENGINEERING
AT THE SCHOOL OF MINES,
COLUMBIA UNIVERSITY,
AS A MARK OF APPRECIATION
AND ESTEEM,
THIS VOLUME IS DEDICATED
BY THE
AUTHOR.

## PREFACE.

There are few engineering works of magnitude that do not involve the excavation of earth. Indeed the cost of earthwork forms one of the greatest of cost items in canal, in reservoir and in railway construction, nor is it an inconsiderable item in the construction of roads, sewers or water works. What will this excavation cost? This is a question that the engineer first asks himself in making his preliminary estimates. Later the same question confronts the contractor. To the engineer an erroneous answer may mean loss of reputation, to the contractor it assuredly means ruin where the work is extensive. A glance at the wide range in contract bids for most earthwork jobs will convince anyone that few contractors do more than guess at costs. While the numberless engineering structures that have cost more than the preliminary estimates prove quite as conclusively that engineers too often guess also.

In this the first published volume treating of earth economics in a comprehensive way, I have given all that my own notes could furnish and all that I could find in print in American technical literature. But I have not confined the exposition to a bare recital of facts and figures, since the principal aim has been to outline rational methods and rules to be used in cost calculation.

As yet many of our teachers of engineering have not impressed upon the students that a truly economic design of a structure can be made only by an engineer who knows every item of actual cost. This in turn can be known only by a study of the tools and methods used in construction. One of the most striking cases in point is the archaic design of standard wagon roadway used to-day in New York State and in Massachusetts

highway improvement. The design dates back to Macadam himself, and is such as to prevent the use of scrapers or road machines. These, as well as many other labor-saving devices used in earthwork, are American inventions, and were not dreamed of a century ago by the eminent English engineers from whom we have inherited our plans and our specifications. A study of costs has taught me not to accept a design because it was "good enough for Macadam," but rather to design a structure with a view to enabling the contractor to use modern tools.

It is hoped that as a class book and as an office book this volume will serve to indicate the proper methods of solving problems of engineering economics in general, and those of earthwork in particular.

H. P. GILLETTE.

New York City, May 20, 1903.

# EARTHWORK AND ITS COST.

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## INTRODUCTION.

### The Art of Cost Estimating.

Engineering design is at once an art and a science. It is the *science* of designing structures, so as to resist the forces to which they are subjected while performing their functions. It is the *art* of so designing these structures that the interest upon their first cost plus annual depreciation plus annual operating expense shall be the least sum possible of attainment. The science of engineering design has been taught—and well taught—in our technical schools for many years, but the art, for the most part, has been left to be acquired haphazard by experience. This is not logical. Indeed it is much easier to master the science of engineering, once the mathematics has been learned, than to master the art. The long list of financial failures due to poor engineering design bear eloquent witness to the statement that the art of engineering is often not learned in the school of experience, or if learned, is learned too late.

I have undertaken in this book to formulate rules and lay down principles to be used by engineers and contractors in estimating the cost of earthwork. The time that I have spent in writing this book can bring little in the way of direct personal return, except such satisfaction as comes to one who has finished a task that others have hesitated to perform. Neither reputation nor emolument follow the writing of such a book; for earthwork "experts" are never sought, and a knowledge of the art of engineering is still

looked upon as of minor importance as a part of one's professional equipment.

It is true that we might point to many a stranded engineering enterprise, wrecked not because the engineers lacked scientific training, but because they had only the faintest knowledge of how to make a dollar in a structure earn the most possible.

It is true that we might point to one State in which macadam roads are costing $5,000 a mile, and to a neighboring State where they are costing $10,000 a mile. It is true that we might point to canal work that has cost several times the "engineer's estimate," and to railways that have a similar financial history. But of what avail? The answer will come from most of our educators that time cannot be spared to teach the economics of engineering. The answer will come from our political governing officers by appointing boards of engineers chosen to estimate the cost of great engineering structures, with not a single member upon the "board" who knows "hardpan" when he sees it. The answer will come from companies who often select engineers to design works because those engineers have written brilliant scientific treatises. The answer will come in the form of public praise of those who have expended the maximum of public funds with the minimum of judgment—provided only that imposing structures bear witness to integrity.

So long as the dollars and cents faculty of engineering students is atrophied by disuse, we can expect little progress in the art of engineering design. Were it necessary to prove that this atrophy is real and not imaginary, we might call attention to the striking dearth of cost data in engineering periodicals and text-books. We might also cite the existence of erroneous and misleading rules for cost estimation that for thirty years have been copied from text-book to text-book without one word of criticism or of disapproval.

We might cite innumerable instances where the meagre cost data given are given without stating the rates of wages or the prices of materials. Indeed it is the exception rather than the rule to find those units stated. Engineers, for the most part, seem to think that the dollar is the only unit needed, forgetting that the real unit is the price of labor per hour.

Let it not be inferred that the writer is advocating the mere gathering of cost statistics very much as boys make collections of birds' eggs or of stamps. It is not the mere collection of facts that is of greatest value, but it is the training in the art of cost estimation that we advocate. It is not what a knowledge of costs denotes, but what it connotes. A student of costs necessarily becomes a careful student of engineering design, and I never so fully appreciated this fact as when I became a contracting engineer, and viewed engineering designs with the eyes of the man out of whose pockets payment for work is directly made. If every designing engineer could for a few years be a contracting or constructing engineer, I feel sure that the world would see many important changes in existing designs, with corresponding saving of public and private funds.

Turning from a consideration of design, as affected by a knowledge of cost to a consideration of an engineer's reputation as affected by a lack of such knowledge, we find a most potent reason why no engineer can afford to ignore this subject. It is almost proverbial that the costs of great public works have far exceeded the engineer's estimates. Witness the following:

| Structure. | Cost — Engineer's estimate. | Cost — Actual. |
|---|---|---|
| Erie Canal (first) | $4,926,738 | $7,143,789 |
| Erie Canal (first enlargement) | 23,402,863 | 32,008,851 |
| Erie Canal (second enlargement) | 12,000,000 | .......* |
| Black River Canal | 1,068,437 | 3,157,296 |
| Hoosac Tunnel | 1,948,557 | 10,000,000 |
| Manchester Ship Canal | 26,000,000 | 67,351,105 |

*After expending $9,000,000 the work was less than one-half (some believe one-third) completed.

Regarding the Hoosac Tunnel, it is only fair to say that this tunnel was the pioneer long tunnel in the United States, and that American engineers in 1854 had had little experience of any kind in tunnel work. But it is given as an example if for no other reason than that it shows the common failure of engineers to consider all the economic factors of great structural works.

CAUSES OF UNDERESTIMATES.—We may now with profit consider why it is that engineers so frequently underestimate the cost of work. I would enumerate them as follows:

1. Failure to train engineering students in the art of cost estimation.

2. Dearth of published cost data.

3. Failure to ascertain by test-pits or borings what kind of material will be encountered.

4. Failure to ascertain just were structural materials will be obtained, and their exact cost laid down at the works.

5. Failure to consider the fact that changes in alinement or design made after beginning work may increase first cost, though desirable because of decreased operating expenses, or cost of maintenance.

6. Failure to allow for the rise in wages and price of materials consequent upon the increased demand generated by the construction work itself —if large.

7. Failure to recognize the fact that high wages breed an "independence" among workmen that results in decreased efficiency.

8. Failure to recognize the fact that a large number of competent foremen is difficult to obtain for large and extended works, resulting in loss of efficiency of each gang.

9. Use of unit prices taken from other contracts of similar nature, without considering that bids may have been unbalanced, or if not unbalanced that the lowest bidder lost money on his work, or that the conditions of work are not exactly similar.

10. Failure to add anything for plant rental and depreciation, also cost of moving plant and lost time.

11. Failure to make allowance for general expenses, such as road building, office expense and foreman expense borne by the contractor.

12. Failure to allow for cost of handling water, snow and ice, and to consider the cost of accidents and delays resulting from bad weather, etc.

13. Failure to add a reasonable margin of profits, or to consider that where 15 per cent. for profit on materials may be fair, 25 per cent. profit on labor is often too low because of the uncertain efficiency of labor.

14. Failure to recognize the fact that contractors may abandon a contract, causing delays in completion with consequent added cost, besides the legal expense.

15. Finally, the fixing of unit prices in a cost estimate before the specifications have been drawn.

Most of these fifteen causes of underestimates are so self-evident that to be appreciated need but to be seen. I shall therefore confine myself to the last-named proposition, which, so far as I know, has never been formulated before, although it is one of the most fruitful sources of underestimates. When an engineer is called upon to design a structure and make an estimate of its cost, he first makes surveys, then plans, and then a bidding or quantity sheet. His next step is to fix upon unit prices, at which he believes reputable contractors will do the work, and so he arrives at his total estimate of cost.

If this cost is satisfactory to the State, municipality, company or private individual employing the engineer, he is directed to advertise or call for bids. Before doing so, however, he draws a set of specifications. Often he is assisted by other engineers in formulating these specifications, very frequently some other engineer has the task of drawing these specifications. I have known cases

where the engineer who made the original estimate of the cost had not seen the specifications until the contracts were awarded! Let us consider the effect of this practice, taking for example a single item, concrete. The engineer who fixed the unit price of the estimate had in mind, we will say, a 1-3-6 Portland cement concrete, which he believed could be made at a profit for $5.50 per cu. yd.

In drawing specifications afterward for this concrete, either he himself or some other engineer decides that a 1-2½-5 will be a better proportion and it is so specified. It is then decided that all sand containing more than 2 per cent. of "dirt" shall be washed, and thus by a few innocent strokes of the pen, both the cost of cement and of sand per cubic yard of concrete are materially increased. Originally the engineer had in mind concrete made of cement in which the barrel of loose cement was the unit, in the specifications the unit is made the barrel of packed cement, thus adding another 20 per cent. to the cement item per cu. yd. of concrete.

The broken stone is next taken up, and the exacting engineer—and how many engineers are not exacting when it comes to drawing specifications—this exacting engineer decides that no stone larger than 1½ ins. in diameter shall be used; and by a few more innocent strokes of his pen decreases the available daily output of the stone crusher by 25 to 35 per cent.; for ordinarily a crusher having a daily output of 60 cu. yds. of stone of all sizes up to 3 ins., will have an output of only 40 cu. yds. up to 1½ ins. Still being determined to get the "very best concrete" possible, the engineer decides to take no risks as to the fine screenings, and specifies rejection of all screenings under ½-in., thus increasing the voids in the broken stone from 33 per cent. with screenings to 45 per cent. without screenings, and so adding to the amount of cement per cu. yd. of concrete.

Finally the engineer having recently seen some

published tests showing that "well rammed" concrete has 5 per cent. greater strength than when only "moderately rammed," inserts a "well rammed" to the satisfaction of the engineer clause, and adds another 15 cts. or so per cubic yard to the cost of the concrete. Thus in the aggregate it is quite possible to add some 30 per cent. or more to the cost of concrete, and so more than take away all profits that existed at an estimate of $5.50 per cu. yd.

But it will be said that the contractor will bid accordingly. Will he? My experience is that he will not, at least the lowest bidder will not, but will govern his bid by the engineer's estimate and by previous bids. If, however, he does raise his price, and so exceeds the engineer's estimate, the work is readvertised until some one is fool enough to bid lower, or "nervy" enough to take his chances against rigid enforcement of specifications.

The work is finally begun; the contractor is not held to specifications because it is apparent that they are unreasonably exacting; some foreman is discharged for incompetency, and makes public the fact that the work is being "skinned;" there is an investigation; new engineers take charge and "stand so straight that they lean over backward;" the contractor throws up his job; the work is relet; and finally a far higher price is paid than the original estimate. Moreover, all of the work is seldom let at one time, hence other contractors hearing of the losses and troubles of earlier contractors bid higher for the remaining work, so that even if the earlier work is finished at prices too low, considering specifications, later work is not done at those low prices. The foregoing is no fanciful picture. Engineers all over the world can bear witness to just such experiences, not once, but many times.

And the cause is the drawing of specifications, either after the engineer's estimate has been made, or the drawing of specifications by men who have

no knowledge of exactly how much each restriction adds to the cost of the work. There are men like the New York State official who said, "I don't care what it costs the contractor, his bondsmen will have to stand the loss. The State is safe, and we are going to have the very best good roads that specifications can be made to yield." Quite so. And the State is now paying for just that kind of "very best good roads." The longer and more exacting a specification, the "better" it is in the eyes of such engineers. The true criterion of excellence is one of dollars and cents, and the best structure is one in which the interest on first cost plus the annual depreciation, plus the annual operating expense, is the least sum attainable in a structure fulfilling the functions for which it was designed.

We may now consider briefly the necessity of accurately determining the character of materials to be encountered or used in construction, although this matter is also treated in the next chapter.

The exact yardage or quantity of excavation is generally known from the surveys within very narrow limits, while the exact character of the material to be handled is often guessed at, or if investigated at all is done very hurriedly toward the end of the survey. Could anything be more short-sighted? It is deemed imperative to establish benchmarks reading often to the one thousandth part of a foot, to plot sections and calculate to the tenth of a cubic yard, and then to ask contractors to bid upon materials about which the engineers know little and the contractors less! In a word the contractor is told just how many cubic yards he is expected to handle, but he is left to guess at yards of what. Where is the contractor who would not sooner guess at the quantities rather than guess at the qualities? If ever railway and other companies awaken to the fact that they have been paying millions of dollars as insurance

upon such guesses, they may be willing to spend a few hundreds to obviate the necessity of guessing. I know of one large railway work, now under way, where not a single test pit was dug, and no classification of earth and rock made, a price being paid for each cubic yard of "excavation" regardless of the material. The price paid was about 50 cents per cu. yd., and the contractors are actually doing the work for about 15 cents per cu. yd.! Pretty stiff insurance rate—that 35 cents per yard!

The engineer who is truly working in the interest of his employer will absolutely refuse to make an estimate of cost or a design of a structure unless he is provided with funds that will enable him to ascertain the character of materials to be encountered, the location of sand and gravel pits, quarry sites, and all similar factors that are necessary to accurate estimation. He will then put this information in such shape as to guide the contractors in making their estimates.

In closing this discussion I would lay down these rules for guidance in drawing specifications:

1. Avoid ambiguity, that is such expressions as "to the satisfaction of the engineer," but state exactly what is desired.

2. Do not prohibit sub-letting; for working by sub-letting is more profitable to the contractor; the profits of the sub-contractor are merely a form of wages for superintendence.

3. Avoid a penalty clause for non-completion of work within the time limit, unless a corresponding bonus clause is inserted. The penalty should not read $50 a day, and the bonus $1 a week, both should be equal.

4. Avoid every kind of wording that may be construed so as to put a contractor "in a hole," or may be used as a club over his head, such as clauses threatening to summarily declare the contract void if "in the engineer's opinion" progress of work is not satisfactory.

5. Avoid every effort to so draw specifications as to avoid a bill of "extras."

An observance of the foregoing rules will result in lower bidding from a better class of contractors. Engineers have so long treated contractors like a set of thieves that it is a marvel so few of them really are thieves, for, according to the adage, "a man may as well be hung for a sheep as a lamb."

A fair engineer will draw fair specifications, if he has an allowance of common sense, for by so doing he will get the fairest prices. Such an engineer will candidly tell his employer that contingencies will probably arise necessitating changes of plans, and he will demand a liberal allowance for just such "extras," instead of trying to avoid bills for "extras" by making his specifications read so as to throw the burden of uncertainty upon the contractor. When he does this, the contractor simply puts in his bill for "extras" before the work is begun, rather than after it is finished, and paying thus beforehand is several fold the more expensive way.

Sub-letting may occasion some annoyance at times, but such annoyance is nothing compared with the gain in dollars. A good foreman makes a better sub-contractor, so reasons the contractor, and he is right. Repeated sub-letting is often to be deprecated, but one or two sub-lettings will generally result in far greater efficiency of the gangs of workmen, and that means a saving in cost to the contractor, and in turn to the company, municipality or State.

# Earthwork and Its Cost.

## CHAPTER I.

### Earth Shrinkage.

Elwood Morris, in 1841, published the results of his observations upon the cost of moving earth by means of carts and wooden drag scrapers. Since that time there have appeared no very noteworthy additions to the literature upon the subject, owing doubtless to the fact that those best fitted to furnish information have considered such knowledge part of their stock in trade. Trautwine's earthwork tables have been widely copied, but they are exceedingly untrustworthy, as we shall presently see. Hill's "Chicago Main Drainage Canal" contains much valuable information, and scattered through periodicals more is also to be found; but so far as the writer knows there is no published attempt at a reduction of existing knowledge to rules easy of application, aside from the above mentioned of Morris and Trautwine.

Before the cost of earthwork can be intelligently investigated a knowledge must be had of its behavior upon loosening, and upon subsequent consolidation.

A great deal of erroneous theorizing has been done, and it will serve to clear the air somewhat, if we give all the results of actual tests, beginning with those of Morris, which are as follows:

| | Excavation, cu. yds. | Embankment, cu. yds. | Shrinkage. |
|---|---|---|---|
| Yellow clayey soil............. | 6,970 | 6,262 | 10.15% |
| Yellow clayey soil............. | 25,975 | 23,571 | 9.25% |
| Light sandy soil.............. | 10,701 | 9,317 | 12.93% |
| Total ...................... | 43,646 | 39,150 | 10.3% |
| Gravelly earth (small scale experiment)...... | | ..... | 12% |

The railroad embankments built by Morris were deposited in layers; one-horse carts and wooden drag scrapers being the means employed in moving the earth. Work was begun in one year, and finished the next, so that it went through one winter before final measurement. According to these experiments 100 cu. yds. of "yellow clayey soil" shrank to about 90 cu. yds. (when packed down by the horses) in the railroad embankment. Note that this shrinkage had all occurred during the progress of the work.

Mr. J. H. E. Hart made some small scale experiments in India, by digging trenches 2 ft. deep and 6 ft. wide, casting out the earth with shovels.

Trench No. 1, in "black cotton soil" measured 416 cu. ft., and the loose earth cast out measured 600 cu. ft., showing a swelling of 184 cu. ft., or 23%, which was checked by immediately shoveling the earth back into the trench without ramming it, when 191 cu. yds. of loose earth were left over after filling the trench level full with loose earth. During the long and very wet rainy season which followed, the earth in the trench settled; and as fast as it did so the loose earth was shoveled in, until at the end of the rainy season only 22½ cu. yds. of loose earth remained, showing an increase of 5.3% over the original measure.

Trench No. 2, in "gravelly soil" (2 ft. deep) showed a swelling of 25% when the earth was thrown out and measured loose in a bank 1¾ ft. high, and after settlement as before under heavy rains of one season, half of the loose material was still left, which was 12½% of the volume of the trench. Note, that in both these cases the earth had not been walked over or pounded when measured loose, and that settlement by puddling action of one season's rains had failed to pack the earth to its original volume.

A. Von Kaven, President of the Royal Polytechnic Institute in Aix-la-Chapelle, gives in his book on Road Building the following; according

to a series of observations when material is first loosened it swells thus:

Sand swells 15 to 20%.
Clay and sand swells 22%.
Hard clay, lias, swells 24%.
Clay mixed with cobbles swells 26%.
Solid gravel bank swells 28%.
Soft rock which can be picked swells 30%.
Hard rock swells 34 to 50%.

While Von Kaven does not state how the material was loosened and measured, in common with other European authorities, he doubtless refers to materials loosened with a shovel and not packed down afterward by traffic, rain, or otherwise.

Mr. Geo. J. Specht, in the Transactions of the Technical Society of the Pacific Coast, May 1, 1885, gives the following as results of measurements made on levee work coming under his own observation:

9,398 cu. yds. in cut (heavy adobe clay) made 9,470 cu. yds. fill measured three weeks after finishing.

10,000 cu. yds. in cut (adobe in sandy loam) made 10,290 cu. yds. in fill.

29,000 cu. yds. in cut (adobe in sandy loam) made 30,330 cu. yds. in fill.

53,350 cu. yds. in cut (sandy loam with small amounts of adobe and hardpan) made 58,350 cu. yds. in fill, or about 9.4% increase.

202,634 cu. yds. in cut made 208,915 cu. yds. fill (3 mos. work).

These data of Mr. Specht's have been so often referred to as proving that earth swells upon being placed in embankment that we have carefully examined every detail of the work as described. The levees were built in 1884 (Aug. 19 to Dec. 16) along the Feather and Sacramento Rivers in Sutter County, California. The levees were about 12 ft. high, 6 ft. wide on top, 90 ft. wide at base with

front slope of 1 in 3, and rear slope of 1 in 4. Material was borrowed from both sides for a distance of 100 ft. from the toe of the slope; and buck scrapers (see Chapter VII.) drawn by four horses were used to move the earth which was not rolled. A buck scraper "drifted" or pushed to place about 90 cu. yds. a day. The soil was well plowed before the fill was placed upon it, to insure a good bond.

We see from the foregoing that there are several noteworthy points of difference between Mr. Specht's work and that of Mr. Morris above given. In the first place, Sutter County, California, is a rainless district in summer. Secondly, the material was taken from the bed of a river and such material is always more dense than ordinary, due to the puddling action at times of high water. Thirdly, no wheeled vehicles passed over the fill during construction, whereas a large quantity of loose earth was pushed into place with the long buck scrapers.

These factors, we believe, combined to make an unusually favorable condition for a swelling of earth when taken from cut to fill.

We would especially emphasize the fact that sandy earth in the bottom of overflowed river valleys, and earth approaching hardpan in certain glacial deposits is very dense. Such earth is quite certain to occupy more space in fill than it did in cut, unless thoroughly rolled or rammed.

Mr. P. J. Flynn, in a paper following that of Mr. Specht in the same volume of transactions (see Eng. News, May 1 and 8, 1886), collected a great array of data on earth swelling and shrinking; and reasoning erroneously by combining the shrinkage of the Morris embankments with the swelling of the Specht embankments, he reached the remarkable conclusion that a contractor should always be made to set his fill stakes $^1/_6$, or 17%, higher than the final grade was to be! The idea being that Specht had measured his fill immediately after completion, while Morris had waited

until rains, etc., had settled it. The error of such reasoning is obvious. The late Prof. J. B. Johnson inserted Mr. Flynn's erroneous rule in his work on "Surveying." In Engineering News, Nov. 15, 1900, the writer called attention to the rule, and questioned its accuracy.

After a series of controversial letters in Eng. News (Nov. 22, Dec. 13, Dec. 20, Jan. 3, and Jan. 10), Prof. Johnson conceded the error of Mr. Flynn's rule.

The following data of bank shrinkage, after the bank has been finished, are taken from the letters of contributors to the aforesaid controversy:

| Authority. | Conditions of fill. | Depth of fill, ft. | Vertical shrinkage |
|---|---|---|---|
| C. H. Tutton.... | Pit gravel for railway fill, by wagons .......... | 14 | 8⅛% after 6 mos. |
| " " | Pit gravel for railway fill, by wagons. .......... | 14 | 9½% " 12 " |
| H. P. Gillette... | Gravelly dike, made by wheelers .............. | 15 | 3% " 4 yrs. |
| " " | Sandy loam, Erie Canal bank ................ | 22 | 3% " 50 " |
| " " | Gravelly road embankment, by dump cars... | 16 | 3½% " 1 " |
| Chas. R. Felton. | Sand and gravel street fill, by carts......... | 5 to 6 | 1¼ & 1% 4 " |
| " " | Same as above, by carts | 7 | 2% after 4 " |
| " " | " " " " | 8 | 1% " 4 " |
| " " | " " " " | 10 | 2¼% " 4 " |
| " " | " " " " | 12 | ½% " 4 " |
| " " | " " " " | 16 | 2% " 4 " |
| " " | " " " " | 18 to 20 | 1½ to 2¼% 4 " |
| Woolsey Finnel | Railroad fills (actual levels), sand and gravel, by wheelers ........ | .. | 1% after 6 mos. |
| " " | Clay, loam and earth, by wheelers ............ | .. | 2 to 3% " 6 " |
| " " | Calico, clay and kaoline, by wheelers ............ | .. | 5% " 6 " |
| " " | Same as above, by carts.. | .. | 8% " 6 " |
| " " | Earth, carts, wagons, cars | .. | 4 to 10% 6 " |
| " " | As above, by wheelbarrows | .. | 15 to 25% 6 " |
| L. B. Merriam.. | Railway fills, by scrapers | .. | 3% |
| " " | " " by wheelers | .. | 5% |
| " " | " " by dump cars | .. | 7% |
| W. F. Shunk.... | " " ............ | .. | 2 to 4%. |

Molesworth (an English authority) says that loam and clay when first loosened swell 20%, but afterward shrink until the fill measures 8% more than the cut. He undoubtedly refers to wheelbarrow work, or shovel work similar to that of Mr. Hart in India, above referred to. Trautwine says that slight shaking compacts loose dry sand 3%,

loam 13%; while ramming in thin layers compacts the loose sand 12% and loam 20%. Gillmore says that 12 cu. ft. of loose sand can be rammed to 9.75 cu. ft., which is equivalent to 20% shrinkage.

The engineer of the Massachusetts Highway Commission, in the 7th Annual Report, gives data from which we deduce that sandy gravel and hardpan upon loosening measured 15% more in the wagon box than in place originally.

The most valuable careful tests made in recent years are those described in Engineering News, June 10, 1902, in an article on the Tabeau Dam. The material in the dam was earth (62%) mixed with gravel (38%).

Material in its natural bank weighed 116.5 lbs. cu. ft.

Material sprinkled and rolled (6-in. layers) in embankment, 133.0 lbs. cu. ft.

Material delivered by wagons, moist and dumped loosely, 76.6 lbs. cu. ft.

Material dug out of dam embankment, loose and shaken, 80.0 lbs. cu. ft.

The natural soil contained 19% of moisture; and 33% of water had to be added to it to fill all voids, making a total of 52% voids in the natural soil when loosened.

From the foregoing we deduce the fact that the natural bank when loosened and placed in wagons swelled 46%, which, if there are no errors, is the highest percentage yet recorded for similar soil, and indicates an unusually dense natural bank. Upon rolling the earth in the embankment there was a shrinkage of about 12⅓% from the original place measure. Let it be noted that the rolled fill weighed about 1¾ times as much as the loose moist earth, and that its weight of 133 lbs. per cu. ft. is almost as great as that of solid masonry! In fact concrete often weighs no more than this earth dam embankment.

The Forbes Hill Reservoir (Mass.) is described in Engineering News, Mar. 13, 1902, and there

also are some valuable facts about earth shrinkage. The embankments were made of clay hardpan containing boulders, and a four-horse plow was required to loosen the hardpan. The following are the volumes of cut and fill:

| | |
|---|---|
| Hardpan, measured before loosening | 17,466 cu. yds. |
| Rolled hardpan embankment | 15,474 " " |
| Shrinkage, 11.4%, or | 1,992 cu. yds. |
| Material excavated, as above | 17,466 " " |
| Estimated equivalent amount of stone (boulders, etc.), removed, 5.9%, or | 1,043 " " |

While the item of stone removed is rather obscurely recorded, it would seem that the natural bank really shrank 1,992 — 1,043 = 849 cu. yds.. or less than 5% during the rolling. After the fill was finished it did not shrink at all during the winter following.

SUMMARY.—From this varied mass of data we may deduce the following general rules or principles:

1. Taking extreme cases, earth swells when first loosened with a shovel, so that after loosening it occupies $1^1/_7$ to $1\frac{1}{2}$ times as much space as it did before loosening; in other words, loose earth is 14% to 50% more bulky than natural bank earth.

2. As an average we may say that clean sand and gravel swell $^1/_7$, or 14 to 15%; loam, loamy sand or gravel swell $^1/_5$, or 20%; dense clay, and dense mixtures of gravel and clay $\frac{1}{3}$ to $\frac{1}{2}$, or 33 to 50%, ordinarily about 35%; while unusually dense gravel and clay banks swell 50%.

3. That this loose earth is compacted by several means; (a) the puddling action of water, (b) the pounding of hoofs and wheels, (c) the jarring and compressive action of rolling artificially.

4. If the puddling action of rains is the only factor, a loose mass of earth will shrink slowly back to its original volume, but an embankment of loose earth will at the end of a year be still about $^1/_{12}$, or 8%, greater than the cut it came from.

5. If the embankment is made with small one-horse carts, or wheel scrapers, at the end of the

work it will occupy 5 to 10% less space than the cut from which the earth was taken, and in subsequent years will shrink about 2% more, often less than 2%.

6. If the embankment is made with wagons or dump cars, and made rapidly in dry weather without water, it will shrink about 3% to 10% in the year following the completion of the work, and very little in subsequent years.

7. The height of the embankment appears to have little effect on its subsequent shrinkage.

8. By the proper mixing of clay or loam and gravel, followed by sprinkling and rolling in thin layers, a bank can be made weighing 1¾ times as much as loose earth, or 133 lbs. per cu. ft.

9. The bottom lands of certain river valleys and banks of cemented gravel or hardpan are more than ordinarily dense and will occupy more space in the fill than in the cut unless rolled.

Earthwork is paid for by the cubic yard, usually measured "in place," that is, in the natural bank, cut, or pit before loosening; but there is no good reason why it should not be measured in the fill or embankment, and it often is so measured where it is very difficult to measure the borrow pits. In either case the specifications should distinctly state how the measurements are to be made. Sand or gravel for mortar and concrete are usually paid for by the load in the wagon. Unless otherwise stated, all the figures of cost in this book are for the cubic yard measured in place before loosening.

## CHAPTER II.

### Earth Classification and Factors in Estimating Earthwork.

Before an accurate estimate of the cost of earthwork can be made the following factors must be determined:

1. The kind of earth.
2. The distance that it must be hauled.
3. The kind of roads over which it must be hauled, including grades.
4. The quantity of earth to be moved.
5. The average depth of cut.
6. The sq. yds. of surface of cut and fill that must be trimmed.

No earthwork can be closely estimated without first digging test pits the full depth of proposed excavation. The common method of driving a steel bar into the ground is apt to be very deceptive, for it may not disclose the existence of quicksand, or of numerous scattered boulders; and even hardpan may be penetrated by a bar. Many contractors have been heavy losers through failure to dig test pits. It is, of course, the engineer's duty to dig such pits, but if he has neglected his duty the contractor should not follow in his footsteps.

Where the soil is tough clay there is frequently a layer of loam about a foot deep over it which, by its apparent ease in plowing, will deceive any one, unless test pits are dug to depth sufficient to disclose the hard clay.

On the contrary, the top 6 to 12 ins. of earth roads and streets are generally packed, forming a very hard crust; while beneath the crust the soil may be readily plowed. Surface indications are in

any case deceptive, and money spent in test pits will be money well invested.

Next to quality of material, the most important factor is the distance to which it must be hauled. We shall use the word "haul" to denote the actual distance traveled with a load in going from the pit to the dump, including turning around. A 500-ft. haul means that a team must travel 500 ft. loaded and return 500 ft. empty. The word "lead" is a convenient one to denote the horizontal distance in a straight line from the center of gravity of the pit to center of gravity of the dump, regardless of distance traveled in turning at both ends. In an extended piece of road or railway work it becomes impossible for the contractor, unless he has a technical education, to estimate the average "lead" very closely, for which purpose he should employ an engineer who, taking the "profile," will estimate the yardage in each cut and the distance it must be moved, tabulating his estimate thus:

| Cut, Sta. to Sta. | Cu. yds. in cut. | Extreme haul in ft. | Average haul in ft. | Material. |
|---|---|---|---|---|
| 0 to 10, etc........ | 1,850 | 2,000 | 1,000 | Clay. |

With this tabulation complete it will be possible to select the best method of handling the earth in each section, as given in the tables that follow. Here, again, we would impress upon the engineer who makes the survey and estimate of quantities that he has performed only half his duties if he stops there. He should also make a tabulation of quantities in each cut, and of distance to be moved in the manner just suggested, showing the results on the profile also, and not leave it to the contractor to do so, as is now almost invariably the practice. Every bit of information that a contractor receives enables him to bid that much the closer. While no company wants a contractor to undertake work at a loss, neither does it want to pay an exorbitant price, one of which contingencies is almost certain to materialize if the company's engineer fails to perform his full duty in furnishing

data. Due to disputes and troubles with contractors over the classification of earth and rock, some engineers pursue the policy of having no classification at all, either paying for the work by the lump sum, by the running foot, or by the cubic yard, using a uniform price for all materials encountered. Such practice on the part of engineers is a costly one for their employers, and cannot be too strongly condemned.

We would suggest a very simple way out of this difficulty of clearly defining in words what is earth from what is "hardpan" or rock. Let the engineer mark on the "profile" what the materials are at each cut, and specify that payment will be made for materials as classified on the "profile" and not otherwise; or if preferred have actual samples of each class of material labeled and filed for reference in case of dispute. Any attempt to define earth, hardpan and rock in words will cause disputes and often lawsuits, or in case of public work, "investigations" that may damage an engineer's reputation, be he ever so honorable and just; for where lines of demarkation are as vague as they are between rock and hardpan, or earth and hardpan, experts can readily be found to give evidence on both sides. An illustration of this is to be found in the now celebrated Erie Canal Investigation Committee's Report.

This committee was appointed by Governor Black to investigate charges of corruption in the departments of New York State having charge of the deepening of the Erie Canal in 1897-8. The Commission's expert, Mr. E. P. North, C. E., took a piece of hardpan that had been exposed for some time to the air, and by letting it soak for some time in water it fell to pieces. This experiment he made to prove that the material should not have been classified as rock. As a matter of fact the writer can state from his own observation that the material in question came under the rock classification, for a plow could not be used even with six

horses attached to turn any kind of a furrow in the hardpan. According to the specification, "material which in the judgment of the Resident Engineer cannot be plowed shall be classified as rock."

Mr. North's experiment was evidently no guide whatsoever in interpreting the specifications, and cast a most unjust suspicion upon State Engineer Adams and his subordinates, a suspicion that the partisan press was not slow to twist into an assertion of fact. This example proves the contention that any classification of materials expressed merely in words (like the plow test) is liable to lead to serious trouble. A classification of materials by samples in the office and by proper records on the profile is susceptible of no such misconstruction.

OVERHAUL.—Formerly it was the universal custom on railroad work to provide an "overhaul" clause in the specifications, the limit of "free haul" being ordinarily 500 ft. Earth hauled any distance within this limit was paid for at a given price of excavation (= cut) of say 20 cts. per cu. yd., if hauled over 500 ft. a given price of say 1 ct. per cu. yd. was paid for each 100 ft. of "overhaul;" that is to say, earth hauled 700 ft. had a 200 ft. overhaul, entitling the contractor to 2 cts. per cu. yd. The overhaul clause has been very generally dropped from recent specifications, but there are several decided advantages gained by its use in certain cases, for a discussion on which we refer the reader to Appendix B on "Overhaul Calculation."

AVERAGE EARTH.—Since earth varies between wide limits both as to its hardness and its weight, it becomes almost impossible to express in words the particular kind of earth to which any reference is made. We have adopted the expedient of using the expression, "average earth," by which we mean any earthy material that may be readily plowed with a two-horse plow. Material that requires little or no plowing to be readily shoveled, as sand, is obviously below "average;" and material requiring great exertion by a single

team, or even of two teams, in plowing is above "average," and more costly both in loosening and in handling generally.

Hair splitting in earth classification is not only confusing, but of no practical advantage.

Therefore, instead of giving voluminous tables showing to the tenth of a cent the cost of moving earth for different "leads," the writer prefers to give simple rules easily remembered. Moreover, he prefers not to classify the different kinds of earth in the rules. In the final summary, Chapter XIII., a small table is given so that a contractor may readily compare the different methods of moving earth and select the most economic. One thing that writers on earth work almost always overlook is that very seldom does the contractor know exactly what the "lead" or haul is going to be. Indeed, on extended railroad work, he generally has to make a rough guess which is certain to be too high or too low. Whereas, even in smaller jobs that can be more carefully "sized up," an error of 25 to 50 ft. in estimating the haul is very common. Hence the absurdity of carrying out earth work costs to fractions of a cent, except to secure uniformity in the tables.

## CHAPTER III.

# Cost of Loosening and Shoveling.

COST OF PLOWING.—A plow or a pick will be used for loosening, the plow being the most economic under ordinary conditions.

Whenever we use the word "team" we mean two horses and their driver; if we refer only to the horses, we shall say a horse or a pair of horses.

A two-horse team with a driver and a man holding the plow will loosen 25 cu. yds. of fairly tough clay, or 35 cu. yds. of gravel and loam per hour. In the far West some contractors always use a four-horse plow even in light soils, but when very tough clay or hardpan is encountered a pick-pointed plow with four to six horses, and two extra men riding the plow beam will always be required, and will loosen 15 to 20 cu. yds. per hour. In such soil a steam roller is very effective, and more economic than horses as a plow puller. One example to show the high cost of plowing the hard crust of an old road will suffice: An old village street, partially gravelled, was plowed up 9 ft. wide × 1,400 ft. long × 14 ins. deep (= 550 cu. yds.) by one plow team with driver and a man holding plow, in 2¼ days, or 244 cu. yds. per day, at a cost of 2 cts per cu. yd. Another similar but harder stretch was plowed with two teams on the plow and a man riding the plow beam, at a cost of 6 cts. per cu. yd. While the average cost of plowing 5,500 cu. yds. of such compacted gravel and earth roadway was 4 cts. per cu. yd. for plowing alone, wages of men being 15 cts. an hour and team with driver 35 cts. an hour. Contractors having old streets or roads to loosen will do well to keep in mind these figures. The foregoing is from the writer's experience.

Morris found that a team, a driver, and a plowman would loosen:
20 to 30 cu. yds. per hour of "strong, heavy soil."
40 to 60 cu. yds. per hour of "ordinary loam."

Specht states that a six-horse plow with one driver and one plow holder would loosen 1,000 cu. yds. of sand, and 700 cu. yds. of sandy loam per day, ready for the buck scrapers to remove.

In this connection it is very interesting to note that if reasoned out "theoretically," as machine work frequently is by inventors and over-sanguine manufacturers, the output of a plow should be many times what it actually is, using "conservative figures" thus: The ordinary plow cuts a furrow 6 ins. deep by 12 ins. wide, so that a team traveling at the very slow speed of $1\frac{1}{8}$ miles an hour (less than half its ordinary walking gait) would loosen 110 cu. yds. an hour, while if it walked right along at its usual gait the amount would be 220 cu. yds. loosened per hour! There has been too much of such "theory" used in estimating the cost of earth work.

COST OF PICKING.—The pick is ordinarily not as economic as the plow, but it must be used in digging trenches and in other confined places. The author has never attempted to separate the cost of picking from shoveling, and there is really but little object in doing so, for where earth is loosened by a pick it is always shoveled up by hand also. M. Ancelin states that a man with a pick will loosen 1.6 to 2.3 cu. yds. earth, 0.7 to 1.1 gravel and 0.9 cu. yds. hardpan per hour. Trautwine gives as a fair day's work an average output per hour of:

| | | Cost a cu.yd. with wages 15 cts. per hr. |
|---|---|---|
| 1.4 cu. yd. | stiff clay or cemented gravel | 11 cts. |
| 2.5 " " | strong heavy soils | 6 " |
| 4.0 " " | loam | 4 " |
| 6.0 " " | light sandy soil | 2½" |
| 20.0 " " | pure sand | ¾" |

PICKING AND SHOVELING.—In trenches and other confined places this method must ordinarily be used. The cost is as follows:

| Material. | Cu. yds. per man, per hr. | Cost per cu. yd. (wages 15 cts. hr.), cts. | Authority. |
|---|---|---|---|
| Hardpan (clay and gravel).. | 0.4 | 37½ | M. Ancelin. |
| Common earth ............ | 0.8 to 1.2 | 19 to 12½ | " |
| Hardpan ................ | 0.33 | 45½ | Cole.* |
| Clay (stiff) ............ | 0.85 | 17½ | " |
| Clay ................... | 1.0 | 15 | " |
| Sand ................... | 1.25 | 12 | " |
| Sandy soil ............. | 0.8 to 1.2 | 19 to 12½ | Gillette. |
| Clayey earth ........... | 1.3 | 12 | " |
| Clay, fairly tough ...... | 0.9 | 17 | " |
| Sandy earth frozen ...... | 0.75 | 20 | " |
| Gravel or clay .......... | 0.7 to 0.8 | 20 | Billings. |
| Earth .................. | 1.1 to 1.2 | 13 to 14 | Hodgson. |

*Gillespie's "Surveying."

As a summary of the table, it may be said that the cost of excavating with pick and loading is for hardpan, 40 cts. cu. yd.; tough clay, 20 cts.; ordinary clay, gravel, or loam, 15 cts.; and very light sandy or loamy soils, 12 cts. per cu. yd., with wages at 15 cts. per hour.

After earth is once loosened and shoveled onto a board platform, as in casting in stages out of a deep trench, one man will shovel off the boards all that two men can loosen and cast up. While a man can with exertion cast earth about 12 ft. vertically from floor to floor, it is best to have floors only 5 to 7 ft. apart. Bear in mind also in trenching that even after the earth reaches the surface it may have to be cast back from the edge of the trench, to make room for all the earth. The cost of backfilling may be ascertained from the next table.

For further information on cost of trenching see Chapter XIV.

SHOVELING.—By vigorous exertion a man may shovel 1 cu. yd. ("place measure") of light loose earth into a wagon in 12 or even 10 minutes, or at the rate of 50 or 60 cu. yds. in a 10-hour day, using the ordinary round-pointed shovel. A man can sprint 100 yds. in 10 seconds or at the rate of 20 miles an hour, yet no one would expect a continuance of the performance all day long. Short-time observations, where a man is working vigorously, should therefore not be made the basis of an

estimate of average cost, as is not infrequently done. Trautwine speaks of the "lost time" of shovelers as being ordinarily about 4 hours out of 10. The expression is misleading, for time spent in rests between the arrival of teams is not time lost, provided the foreman insists upon vigorous exertion while actually working. A man may shovel only 20 minutes out of an hour, yet accomplish exactly as much in a day as another man shoveling steadily. Bear in mind that men need not be kept steadily busy, provided that when they do work they make up for the time "lost" in resting; and the same is true of horses.

At the 17th annual meeting of the Connecticut Civil Engineers' and Surveyors' Association, Jan. 8, 1901, Mr. G. A. Parker, Supt. Keney Park, Hartford, Conn., gave the following as the results of his experience:

The bank was loose sand requiring neither picking nor plowing. Material was shoveled into two-horse carts holding 1 cu. yd. It is not stated whether the measurement was of loose sand in cart or packed sand in bank, but apparently measurement was made in carts. It required 150 shovelfuls to make a cubic yard, and a man by shoveling 25 secs., then resting 25 secs., would average five shovelfuls loaded in 50 secs., or 22.8 cu. yds. in 10 hrs. after deducting 5% for waste time. Each man counted his shovelfuls, and was allowed to cast only five shovelfuls before the team moved on. There were 15 shovelers in a gang and two gangs in the pit.

Mr. Parker claims that the results justify his statement that this is the best known method of working men, as it gives them needed rests, and keeps their minds active. We would observe that it might not work so well where soil is tough; and that just as high outputs have been obtained by the common methods where sand was loaded.

The amount of earth that a man will handle per hour with a shovel varies not only with the char-

acter of the soil, but with the method of attack. If a man is shoveling from a face of earth over a foot high, one that he can readily undermine with a pick, for example, he can load 1.8 cu. yds. an hour on an average; while if he is shoveling plowed soil, where he must use more time to force the shovel down into the soil, his output will be about 1.4 cu. yds. per hour. If he is shoveling loose earth off boards upon which it has been dumped, his output is about 2.5 cu. yds. per hour.

The size of the shovel makes a marked difference also. In tough soils a small round-pointed shovel that will easily penetrate must be used; but it is folly to permit shovelers to use any except large square-pointed scoops in handling earth off boards, or in shoveling sand, unless it has to be cast some distance. With a large square-pointed scoop a strong man can load sand into a wheelbarrow at the marvelous rate of 5 mins. per cu. yd. Finally there is to be considered the actual volume of earth held by the ordinary round-pointed shovel, and the number of shovelfuls cast to varying distances in a given time. The author, from some observations, can say that roughly speaking it takes 150 to 250 shovels of earth to make a cubic yard in casting into a wagon box, and at a good steady gait, seven shovels are loaded per minute. This is for a vertical lift of about 5 ft., but in casting out of a trench with a vertical lift of 10 ft., only five shovels are cast per minute.

Casting earth horizontally shows a similar variation; nine shovels per minute for a 5-ft. horizontal cast, and about half as many for an 18 or 20-ft. horizontal cast.

From these observations we may draw several practical conclusions: First, with wages at 15 cts. per hr., it costs about 5 cts. to carry a cubic yard 10 ft. in shovels; hence men should be close enough to the wagon not to be required to take even a few steps before casting; second, the farther away a man is from the wagon the less number of shovels

he can cast in a given time, and as each shovelful is also smaller, a man some 12 or 15 ft. away from the wagon will load about half as much as if he were upon within 4 or 5 ft. of it; hence it does not pay to crowd men around a wagon (six is about enough), acting upon the foolish idea that quick loading saves money by saving team time; third, use large square-pointed shovels wherever possible; fourth, work to a face whenever possible; fifth, lay down a temporary floor at the face, so that earth picked down will fall on the floor from which it can be easily shoveled, which is done in mine tunneling to great advantage and should be done oftener in earth work generally; sixth, undermine a high face of earth with picks, then drive bars on top to wedge it off, thus loosening earth (not clayey) cheaper than with plows. Picking is not much more costly than plowing anyway; and where a high face is worked it becomes less so, while at the same time, the cost of shoveling is reduced; for wherever earth is plowed, the teams and men soon tramp it down, making shoveling difficult. Finally it should be said that wherever possible men should be paid by the cubic yard—not by the day; for working thus, they work faster.

COST OF LOADING INTO WAGONS.

| Material. | Cu.yd. per man, per hr. | Average cost in cts. a cu. yd.; wages 15 cts. hr. | Authority. |
|---|---|---|---|
| Mud into wheelbarrows .... | 0.8 | 19 | M. Ancelin. |
| Gravel into wheelbarrows... | 1.7 to 2.7 | 7 | " |
| Earth into wheelbarrows..... | 1.6 to 4.8 | 5 | " |
| " " " av'g.. | 2.2 | 7 | " |
| " " " ...... | 2.8 | 5¼ | Gillespie. |
| " (all kinds) into wagons | 2.1 | 7½ | Cole.* |
| " ......... ......... | 2.0 | 7½ | D. K. Clark |
| Sand into cars from high face | 1.8 | 8¼ | Gillette.† |
| Gravelly soil into wagons after plowing ........... | 1.3 | 11½ | Gillette.‡ |
| Iowa soil ................. | 1.5 to 2.0 | 8½ | J. M. Brown |
| Iowa soil .................. | 2.8 | .. | §J. M. Brown |
| Clay and gravel into carts.. | 1.0 | 15 | E. Morris. |
| Loam into carts.......... .. | 1.2 | 12½ | " |
| Sandy earth, into carts..... | 1.4 | 10¾ | " |
| Loose sand into carts....... | 2.0 | 7½ | G.A. Parker |

*Ten miles; Erie Canal.
†10,000 cu. yds., measured in bank
‡20,000 cu. yds., in embankment.
§A rush job.

Note.—While the figures of Morris are based upon many thousand yards of excavation, the low output is undoubtedly due to the fact that the earth was all shoveled from plowed soil, and possibly not thoroughly plowed at that. The example from the writer's experience of 1.3 cu. yds. per man-hour was with a very "easy-going" foreman, which may have been likewise the case with Morris. An engineer should base his estimate of cost on about 1.4 cu. yds. loaded per man-hour; whereas a contractor, who knows his foremen to be efficient, may figure on about 25% better output, or as high as 2.0 cu. yds. an hour, and in exceptional cases on short rushed jobs 2.8 cu. yds. of soil per hour. See also Chapter VI for further information on shoveling.

## CHAPTER IV.

### Cost of Dumping, Spreading, Rolling, Etc.

DUMPING.—Time is consumed in dumping wagons, carts, wheelers, or wheelbarrows; and small as the time may be in each instance, it becomes a very important item in the daily aggregate, especially when the haul is short.

One man, aided by the driver of a slat-bottom wagon holding ¾ cu. yd., will dump it and replace the sides and bottom in 1½ mins., at a cost of 0.4-ct. per cu. yd. for the dumpman's time and 0.8-ct. per cu. yd. lost team and driver time. It takes 3 mins. to dump a larger wagon box holding 1½ cu. yds., where the driver removes the seat before dumping, and replaces it afterward; while it takes about 5 mins., if, in addition to the regular operation of dumping, a "binder chain" is wound around the box to hold the slats close together to prevent spilling of earth on city streets. Patent drop-bottom dump-wagons holding 1½ to 2 cu. yds. can be dumped in ¾-min. by the driver alone at a cost of ⅓ to ¼-ct. per cu. yd. When a haul becomes so long that the time spent in dumping is less than about one-fifth the time required to travel from pit to dump, then it is not necessary to charge anything for lost team time at the dump; for the teams get only a needed rest, for which they will readily make up by walking a little faster on the return trip empty. It follows that on hauls of over 1,500 ft., using ¾-cu. yd. wagons, there is no advantage in substituting patent dump wagons, even at a saving of time at the dump. On the contrary, where 1½-cu. yd. wagons can be used, the patent dump-wagon shows a saving for hauls less than ¾-mile, but little or none for greater hauls. There is one other condition where a patent dump-wagon is advantageous, and that is where no spreading is

required, and where wagons do not come close enough together to keep a man at the dump busy helping drivers dump their wagons. For example, if $1\frac{1}{2}$-cu. yd. wagons deliver 15 cu. yds. an hour at the dump, it will cost 1 ct. per cu. yd. for the time of the dump man; where, as a matter of fact, he could handle twice as much at a cost of $\frac{1}{2}$-ct. per cu. yd., if it were delivered faster. The size of the gang in the pit determines the output, and where possible should be large enough to keep the dump-man busy.

The driver of a one-horse cart will dump it in about 1 min., so if the cart holds $\frac{1}{3}$ cu. yd. the cost of lost time in dumping, wages of driver being 15 cts. and horse $7\frac{1}{2}$ cts. per hour, is $1\frac{1}{4}$ cts. per cu. yd.

A wheelbarrow is dumped in about $\frac{1}{4}$ min., but as it only holds $^1/_{12}$ to $^1/_{16}$ cu. yd. there are 3 or 4 mins. per cu. yd. lost in dumping, making the cost 1 ct. per cu. yd.

No matter what the method, we see that the cost of dumping is seldom much less than 1 ct. per cu. yd.

SPREADING.—Trautwine states that a bank-man will spread 5 to 10 cu. yds. an hour. M. Ancelin says $4\frac{1}{2}$ to 9 of earth, 3 to 8 of gravel, and $2\frac{1}{2}$ of mud is the average cubic yardage spread per man-hour.

If the work is crowded, or not on a scale sufficiently large to warrant using a leveling scraper, estimate $7\frac{1}{2}$ cu. yds. spread per man-hour. On more extensive work, where a team can turn around, use a Shuart grader; or, if there is abundance of room for turning, a road machine with three teams attached may be used.

After dumping earth from slat-bottom wagons, each load in three piles, the writer has used a Shuart grader, which with one team and driver and a helper will spread 50 cu. yds. per hour.

Three teams with a driver and a helper on a road machine will spread 90 cu. yds. of earth an hour from piles left by patent dump-wagons, spreading

the earth in 6-in. layers. Thus the cost will vary from 2 cts. per cu. yd. by hand labor to ½-ct. by Shuart grader, to 1 ct. by road machines.

RAMMING AND ROLLING.—A man can thoroughly ram or tamp in 6-in layers 2½ cu. yds. per hour at a cost of 6 cts. per cu. yd.; but where the soil is not clayey, consolidation may often be more effectually and cheaply done by puddling with water.

A 5-ton roller with a 60-in. face, drawn by three teams handled by one driver, will consolidate about 100 cu. yds. an hour, at a cost of ¾-ct. per cu. yd. One team on a 2-ton grooved roller will travel ten times over a 6-in. layer at a speed of 90 ft. a minute, including rests, thus consolidating at a cost of about ½-ct. per cu. yd. where team and driver wages are 35 cts. per hour.

As an example showing the highest probable cost of spreading and rolling a reservoir bank where extraordinary care is required, the Forbes Hill Reservoir, described by Mr. C. M. Saville in Engineering News, May 13, 1902, may be cited. The material was hardpan (clay and gravel) spread in 4-in. layers by hand, all cobbles over 3 ins. diameter being removed. The sprinkling was done from a water pipe and hose. Corrugated rollers weighing two short tons each, and drawn by two horses, were used. Laborers were paid 15 to 17 cts. per hour, teams 45 to 50 cts. The dumping of wheel-scrapers and spreading by hand cost 7.7 cts. per cu. yd.; and the rolling cost 3.9 cts. per cu. yd. measured in cut. There is evidence, however, indicating poor management in doing this work, of which more will be said under wheel-scrapers.

In reservoir embankments, harrowing may be required, in which case a team and driver upon a harrow may be counted upon to harrow about 100 cu. yds. an hour.

SPRINKLING.—Sprinkling of embankments, where specified, is usually required to be "to the satisfaction of the engineer"—a form of wording

that always seems like an attempt to hide ignorance under a cloak of ambiguity. Seldom should more water be required than would fill the voids in the packed earth, say 8 cu. ft. of water per cu. yd. of earth; and as a rule not over half as much is required to secure satisfactory puddling.

On a large embankment three sprinkling carts, each drawn by three teams, with one driver, sprinkled 1,000 cu. yds. of earth per day of 10 hrs., with short haul. Such carts each held 150 cu. ft. of water weighing $4\frac{1}{2}$ tons, which is an exceedingly large cart. A sprinkler of this capacity can be loaded from a tank in 15 mins., and emptied in the same length of time. Knowing the length of haul and speed of team (see Chapter VI.) the cost of sprinkling is readily determined. In the case just given the cost was $2\frac{1}{4}$ cts. per cu. yd. of earth for sprinkling and about 5 cu. ft. of water per cu. yd. were used. A man with a good hand pump will raise 1,000 cu. ft. of water 16 ft. high in 10 hrs. into a tank, making the cost of pumping in this case by five men for the 1,000 cu. yds. of earth sprinkled, $\frac{3}{4}$-ct. cu. yd. Had a small engine burning $\frac{1}{2}$ ton soft coal a day and an engineer at $2.50 a day been employed, the cost would have been about half as much for the pumping item.

TRIMMING.—Gillespie, the only authority giving data on this item, says that a man will trim 11 sq. yds., or about 100 sq. ft., surface measure of embankment per hour. The writer is inclined to think that Gillespie's estimate of cost is altogether too high; for a man can pick and shovel 2 cu. yds. of embankment an hour, at which rate he would be able to "trim" to a depth of 6 ins. if he covered only 11 sq. yds. of surface per hour, whereas trimming, "smoothing," or "sandpapering" requires a moving of about 2 ins. of earth instead of 6 ins.

From several careful observations the writer has found that a gang of men under a good foreman will each trim the sod and humps off the hard surface of a cut to the depth of 1 or $1\frac{1}{2}$ ins. at the rate

of 200 sq. ft. or 22 sq. yds. per hour, at a cost of ⅔-ct. per sq. yd.; and where there was no sod to remove, the soil being sandy loam, the cost was one-half as much or ⅓-ct. per sq. yd. Massachusetts contractors bid almost uniformly 2 cts. a sq. yd. for "surfacing" (wages 17 cts. per hour), which includes rolling the finished surface with steam roller. A roadway, including ditches, 36 ft. wide and a mile long, has 21,000 sq. yds. of surface, which at ⅔-ct. is $140, actual cost of trimming. If the total excavation in a mile is 3,500 cu. yds. (which is about the average in N. Y. State), the cost of trimming, distributed over this 3,500 cu. yds., is 4 cts. per cu. yd. of excavation, a cost much greater than a mere guess would lead one to expect.

If "sandpapering" is specified, it is evident from this that the item of trimming must not be overlooked; and the shallower the cuts, the greater its relative importance as an item of cost. A Shuart grader, a "road machine," or similar tool will do the trimming of comparatively flat surfaces that are over 6 ft. wide for a very much less sum than by the shovel and mattock method; in fact, the cost is so slight, being merely nominal, that it may then be entirely omitted from the estimate. The author has directed the scraping of a light growth of weeds and grass off the 4-ft. shoulder of a road by going once over it with a Shuart grader, at a rate of 200 sq. yds. per hour, or ten times faster than a man with a mattock would have done it; making the actual cost about ¼-ct. per sq. yd. where the team, driver and helpers' wages were 50 cts. per hour. As illustrating both poor design and poor management, the Forbes Hill Reservoir experience may again be referred to; for very often contractors are compelled by specifications to do just such needlessly expensive work as the following done at Forbes Hill: "In order that the portion of the banks near the inner slope might be rolled as thoroughly as other portions, the bank was built

with an extra width of 1 ft. and afterward trimmed to grade." In trimming, the slope of the bank (hardpan rolled) was first plowed, and the material was cast down to the bottom with shovels. The final trimming was done with picks and shovels. Labor cost 15 to 17 cts. per hour; teams 45 to 50 cts.; and 1,500 cu. yds. were thus trimmed off. The loosening cost 56 cts., and the loading into carts 30.6 cts. per cu. yd., or a total of 86.6 cts. for loosening and loading each cubic yard of earth! What more need be said of such practice?

Yet it is by no means unusual, and a contractor cannot be too careful in examining earth work specifications for reservoir embankments before bidding.

## CHAPTER V.

### Cost by Wheelbarrows and Carts.

Barrows are never economic except in muddy places where horses would mire, or in narrow confined places, or in moving very stony soils short distances.

Trautwine assumes that a man will load and dump a wheelbarrow in 1¼ mins., the barrow holding $^1/_{14}$ cu. yd., and that a man will travel 200 ft. a minute. He further allows 10% "time lost" in rests. His tables of cost are about right for hauls of ordinary length, such as a 100-ft. haul, but are grossly in error for short hauls, as for 25 ft., where, by his false assumption that a barrow can be loaded in 1¼ mins., he makes an output of 25.7 cu. yds. in 10 hrs. per man; the actual output being not much over half as much. The error arises from a short-time observation where insufficient time was allowed for necessary rests.

From careful observations the author has found that a man walks at a speed of 250 ft. a minute, and loses ¾-min. each trip, dumping load, fixing run plank and resting; and that it takes 2¼ mins. to load a barrow holding $^1/_{15}$ cu. yd. place measure of earth already loosened (rate of loading being 1.8 cu. yds. an hour), and in this the author is confirmed by Cole's observations (see Gillespie) on the Erie Canal.

In repairing breaks in a levee where the material was very sticky adobe clay, Mr. Specht made the following observations as to cost: Haul 208 ft., rise 7 ft., load in wheelbarrow $^1/_7$ cu. yd., 7½ mins. per round trip; output per Chinaman on wheelbarrow, 10.8 cu. yds. in 9½ hours of actual working time.

| | |
|---|---|
| 10 Chinese on wheelbarrows, at $1.50 | $15.00 |
| 3 Chinese at $1.50 | 4.50 |
| 1 White foreman | 2.50 |
| 108 cu. yds. per day at 20.4 cts. | $22.00 |

It will be noted that the load of a wheelbarrow given by Specht is double that ordinarily given. We believe it to be misleading, since $^1/_7$ cu. yd. of clay would weigh 350 to 400 lbs., and not even a Chinaman would move such a load as that day in and day out. Based upon the writer's data given in this and preceding chapters we formulate:

RULE I.—To find the cost per cu. yd. of picking, shoveling, and hauling average earth in wheelbarrows, multiply the wages of a laborer per hour by $1^1/_6$, and add $\frac{1}{3}$ or an hour's wages for each 100 ft. of haul. When wages are 15 cts. per hour this rule becomes: To a fixed cost of $17\frac{1}{2}$ cts. add 5 cts. for each 100 ft. hauled.

CARTS.—The method of hauling with one-horse two-wheeled dump-carts is especially adapted to work in narrow cuts, basement excavations, and wherever the haul is short; but in such places wheel scrapers are ordinarily better, unless the haul is over street pavements.

The great advantage that carts possess over wagons is ease of dumping (one man can dump them) and especially of dumping into hoppers, scows, etc. The data of Morris, who kept account of the cost of moving 150,000 cu. yds. of earth with carts are the most reliable in print. In his work one driver was required for each cart. Trautwine erroneously assumes that one driver can attend to four carts. For the short hauls upon which carts are ordinarily used one driver can attend to not more than two single horse carts. Morris found the average speed to be 200 ft. a minute, and the average load $\frac{1}{3}$ cu. yd. (bank measure, equivalent to 0.37 cu. yd. place measure) on a level haul; $\frac{1}{4}$ cu. yd. on steep ascents, and there were 4 mins. of "lost time" loading and dumping each trip. As we have above stated, the cost of picking and shoveling average earth is one hour's wages per cu. yd., while if earth is loosened by plow the cost of loosening is about $^1/_{20}$-hr. wages of team and

driver, and the cost of loading plowed earth is $\frac{2}{3}$-hr. wages of laborer per cu. yd.

Upon these assumptions, and accrediting a driver to each cart with an average load of $\frac{1}{3}$ cu. yd., we formulate:

RULE II.—To find the cost per cu. yd. of plowing, shoveling, and hauling "average earth" with carts, add together these items:

> $^1/_{20}$-hr's. wages of team and driver and helper on plow;
> $^2/_3$-hr's. wages of laborer shoveling;
> $^1/_4$-hr's. wages of cart horse and driver for "lost time."

To which add $^1/_{20}$ hour's wages of cart, horse and driver for each 100 ft. of haul. With wages of a man at 15 cts. and of a horse at 10 cts. per hour, this rule becomes: To a fixed cost of 18 cts. add $1\frac{1}{4}$ cts. per cu. yd. per 100 ft. of haul.

N. B. If one driver attends to two carts, as is very often the case, the hauling item is $^1/_{40}$ hour's wages of a man and two horses, or 0.9 cts. per cu. yd. per 100-ft. haul at wages above given. In cities where streets are level, and hard, even if not paved, one-horse carts holding $\frac{2}{3}$ cu. yd. are used; furthermore horses travel faster than the 200 ft. per minute given by Morris on railroad work, 220 to 250 ft. a minute being the speed at a walk over hard level roads. With large $\frac{2}{3}$-yd. one-horse carts and one driver to each cart, the cost of hauling per cu. yd. per 100 ft. is therefore, $^1/_{45}$ hour's wages of horse and driver, or $^5/_9$ ct. per cu. yd. per 100 ft.

## CHAPTER VI.

### Cost by Wagons.

There are two sizes of wagon boxes for two-horse slat-bottom wagons commonly used by contractors; the small box 3 ft. wide, 9 ft. long, and 12 ins. deep inside measure; and the large box with sides 4 to 6 ins. deeper. The small box holds just 1 cu. yd. struck measure of loose earth, which, as we have seen, is equivalent to about 0.8 cu. yd. measured in cut; and this is all that a team can haul over temporary or soft roads such as are encountered in railroad, reservoir work, or the like, where steep uphill pulls are common. Cole (see Gillespie) gives the average load at $\frac{2}{3}$ cu. yd. place measure, on canal work that he was in charge of. In city work, and generally in any road improvement work, where the roads are hard earth, even though there may be occasional short level pulls at each end of the haul through plowed earth, the large wagon box may be used with a load varying from $1\frac{1}{4}$ to $1\frac{1}{2}$ cu. yds. place measure; the average given in the Seventh Annual Mass. Highway Comr's Report was 1.4 cu. yd.

In Chapter II. were given some data about slat-bottom and patent dump wagons which will not be repeated here. There are certain other important details about wagon hauling that must be briefly touched upon.

The average speed of a team walking steadily over hard roads with a large load, and returning at a walk empty, is about $2\frac{1}{2}$ miles an hour, or 220 ft. a minute. If there are any delays in loading or unloading, a team can usually make up for such delays by trotting back at 4 or 5 miles an hour, if the roads are hard and level; so that where engineers often criticise contractors who appear to be losing money when teams are standing idle, the truth may

be that the team is daily covering its 20 miles on earth roads to 25 miles on paved roads—all that can be expected anyway. Thus with a haul of 1¼ miles or more from a sand pit, it does not pay to employ shovelers to load the wagons, for each driver can load his own wagon in 25 mins. with 1⅓ cu. yds. of sand. The driver then gets a long rest while the team works; and by trotting the team back it will cover 20 to 25 miles in the day, unless it happens that the length of haul is such that an even number of round trips cannot be made in the 8 or 10 hours available. Where the hauls are long, contractors should bear this last fact in mind, otherwise it may transpire that the hauling will cost some 20% more than is estimated, unless the teams can be used in plowing or otherwise for an hour or so daily, to piece out the full day. Ordinarily 15 to 30 mins. are lost each morning in waiting to be loaded. Where the hauls are ½ mile to 1¼ miles, one man in a sand pit to help the drivers load is all that is needed for economy. On short hauls, under favorable conditions, the method of using extra wagons is especially to be recommended. The extra wagons are left in the pit, and one or more men load them while the team is gone; upon its return, the teamster changes from the empty to the loaded wagon in about 1½ mins. By this method both shovelers and teamsters are in a treadmill where it is easy to fix responsibility for loafing, so that one foreman, or even no foreman at all, is needed for constant supervision of both gangs. This plan is good also where hauls are long and over soft roads where teams cannot trot back making up for lost time.

Where teamsters' unions exist, as in some cities, teamsters will frequently refuse to do any shoveling at all. On any work, unless teamsters are distinctly given to understand at the start that they must shovel when ordered, and must use the kind of wagon box designated by the contractor, there will be a strike unless work is scarce.

A contractor should always be guarded in counting upon any money-saving methods wherever he finds wages are high; for high wages generally indicate a scarcity of men, which in turn means that they will leave at the slightest provocation. Strange as it may seem, while well-paid men are the most cheerful workers, a rising labor market breeds an independence among the laborers that makes it often impossible to secure a fair day's work.

For example, well-paid teamsters had been hauling 1¼ cu. yds. of stone over hard earth roads and steep grades, but upon changing them to level macadam roads they refused to haul any greater loads, despite the fact that with no greater exertion a team could haul 2½ cu. yds. Nothing but the purchase of a few teams by the contractor prevented a strike, and secured proper loading.

It is human nature apparently to "make the job last," although it is a mistaken economy in the end to do so. Dishonest teamsters will frequently pull out one of the bottom slats of their wagon, and drop the side boards so that the wagon will hold about ¼ cu. yd. less than it is supposed to. Binding chains around the body are often drawn up so tight as to pinch the top of the side boards in 6 ins. The seat may not be removed in loading, leaving a large unfilled space at the front end of the wagon. An inexperienced or inefficient foreman, by not guarding against these things, will cost his employers several times his salary.

The large wagon boxes should be used wherever possible, and occasionally it may pay to have a "snatch team" to get a load out of the pit, or over steep hills; but a snatch team never pays where the haul is much less than ¼ mile. Where the hauls are very long, teams can travel in pairs and upon coming to a steep grade can help one another over it, each acting in turn as the snatch team for the other.

Finally, as another expedient for increasing the size of wagon loads there is the use of a three-

horse team, three horses being worked abreast; for thus the fixed expense of the driver is reduced by one-third, since a load fully 50% greater can be hauled by three horses than by two. Three horses cannot pull exactly together, but this is made up for by the decrease in the proportionate dead load of the wagon, and by the decrease in the coefficient of friction under greater wheel loads.

In the far West two teams are often hitched to one wagon, driven by one man; but it is not easy in the East to find "four-in-hand" drivers.

Recently the writer came across some valuable data given by Mr. J. M. Brown in the Transactions of the Iowa Society of Engineers, 1885, from which the following was abstracted:

The earth was Iowa surface soil excavated to make a railroad embankment. Two-horse wagons holding 1.6 cu. yds. were used when hauls became 800 ft. or more; for shorter hauls wheel scrapers were used (see next chapter). There were five to seven shovelers to load a wagon, each man shoveling 15 to 20 cu. yds., average 17 cu. yds. per day of 10 hours. For an 800-ft. haul the force used was:

1 Plow team, driver and man holding plow.
21 Shovelers (3 gangs of 7 each).
9 Wagons (3 gangs of 3 each).
1 Foreman.

The earth moved by this force was 360 cu. yds. in 10 hours. With wages at 15 cts. for laborers and 35 cts. for team with driver per hour, including an allowance for wear and tear on tools, the cost was:

| | Per cu. yd. |
|---|---|
| Plowing | 1.66 cts. |
| Shoveling (17 cu. yds. per man) | 8.75 " |
| Foreman and dumping | 1.20 " |
| Total | 11.61 " |
| Hauling (including lost time) 800 ft. | 9.03 " |
| Grand total | 20.64 " |

Since each team hauled only 40 cu. yds. 800 ft. in 10 hours at a cost of 1⅛ cts. per cu. yd. per 100 ft. it would appear at first sight that the wagons could not have held 1.6 cu. yds. each as stated; but when time of team lost at each end of haul in waiting to load and dump is considered, we have an explanation of the high cost of 9 cts. for an 800-ft. haul. Mr. Brown adds that for every 200 ft. of added haul, one more team must be added to the force above given, which is about right, but indicates that no such load as 1.6 cu. yds. place measure was carried. As illustrating what can be done when work is rushed and the force driven to its limiting capacity, Mr. Brown gives an example of an embankment 1¼ miles long, 10 ft. high, containing 97,500 cu. yds. built in 20 days. The haul was by wagons from borrow pits 1,300 ft. away. Each team made 40 trips a day, or nearly 20 miles; each man loaded 28 cu. yds. The cost was 5.46 cts. for shoveling, 6.25 cts. for team time on wagons, and 6.87 cts. for plowing, clearing, foremen, etc. Estimating backward from these data it appears that each wagon carried about 1¼ cu. yds., which, as above stated, is in accord with the author's experience.

The following examples of the cost of loading and hauling with wagons are taken from the writer's time-books:

Cellar Excavation, No. 1.—35 men shoveling, 10 men picking and trimming, output 500 wagon loads of sandy earth in 10 hours; each wagon averaged 1½ cu. yds. loose measure, so that each shoveler loaded 21 cu. yds. of loose earth per day, which was probably equivalent to 16 cu. yds. in cut.

Cellar No. 2.—14 shovelers loaded 23 wagon loads in 75 mins., or at the rate of one wagon load per shoveler in 45 mins. Wagons held 1½ cu. yds. loose measure, hence each shoveler averaged 20 cu. yds. loose measure in 10 hours, which is probably equivalent to 16 cu. yds. in cut.

Later, 8 shovelers loaded the same wagons in from 3 to 5 mins. time for each wagon load, the average of 10 loads being 4 mins., which is equivalent to a rate of 27 cu. yds. loose earth shoveled per man-day or say 21 cu. yds. in place. The haul was 4,350 ft., over level pavements, except at the pit and at the dump, and the round trip took 29 mins. on an average, teams jogging back part of the way at a trot, so that the average speed going and coming was 300 ft. per min. The earth was easily plowed by one team with a driver and a plowholder who loosened 300 cu. yds. a day. It will be noted that when 14 shovelers were crowded about each wagon, each shoveler loaded at the rate of a wagon load in 45 mins. as compared with 32 mins. when only 8 shovelers were engaged, showing the poor economy resulting from crowding the men about the wagon.

Embankment Approach to Bridge.—8 shovelers in pit, 1 man on dump, 7 teams hauling wagons, 1 team plowing; output, 140 wagon loads of gravel per 10-hour day, with a 3,000-ft. haul. Road level, except coming out of pit, wagon load, 1 cu. yd. loose measure, 17½ cu. yds. loose gravel loaded per shoveler which is probably equivalent to 13 cu. yds. in place; each team traveled 22½ miles daily; time lost in dumping was 1 min.

Dike No. 1.—3,800 cu. yds. sandy gravel measured in fill, hauled 2,000 ft., required 300 man-days and 150 team- (with driver) days, at a cost of 25½ cts. per cu. yd.; 12¾ cu. yds. per man-day, including dump men, and 25⅓ cu. yds. per team-day, including plow teams.

Dike No. 2.—6,500 cu. yds. of loam, measured in fill, moved 800 ft. on an average with wagons and No. 2 wheel-scrapers, of which 3,700 cu. yds. were hauled 1,100 ft. with wagons, and 2,800 cu. yds. were hauled 400 ft. with wheelers, 380 man-days (10 hrs.) at $1.50, and 280 team-days at $3.50 were required, making the cost 24 cts. per cu. yd. as the average of both wheelscraper and wagon work.

6 shovelers load a wagon with 1¼ cu. yds. loose measure in 3½ mins., and the man on the dump helped by the driver dump wagon in 1 min.

Dike No. 3.—5 shovelers at $1.50 per 10-hr. day, 2 teams at $3.50 and 1 man dumping and spreading, moved 540 cu. yds. coarse gravel, measured in fill, a distance of 1,600 ft., in 8½ days; 12¾ cu. yds. per day per shoveler; 31¾ cu. yds. per day per team; 63½ cu. yds. per day per dumpman.

Based upon the data given in preceding chapters and upon that given in this chapter (except Mr. Brown's data) we formulate the following:

RULE III.—To find the cost per cu. yd. of average earth moved in ¾-cu. yd. wagons, add the following items:

$^1/_{20}$ hour's wages of team with driver and helper plowing;

⅗ hour's wages of laborer shoveling;

$^1/_7$ hour's wages of team with driver, "lost time;"

$^1/_{15}$ hour's wages of laborer dumping wagons. Then add finally $^1/_{50}$ hour's wages of team with driver for each 100 ft. of haul. With wages of men at 15 cts. and of team with driver at 35 cts. per hour this rule becomes: To a fixed cost of 18 cts. per cu. yd. add 0.7 ct. per cu. yd. for each 100 ft. of haul over soft earth roads with steep ascents; or 0.4 ct. per cu. yd. for each 100-ft. haul over hard level earth roads where wagons holding 1.3 cu. yds. can be used (see first part of this chapter).

## CHAPTER VII.

### Cost by Buck and Drag Scrapers.

COST BY BUCK SCRAPERS.—The buck scraper was originally an upright board about 8 ft. long and 2 ft. high, shod at its lower edge with iron, provided with a tongue for the team in front, and a platform at the rear upon which the driver could stand. During loading the driver would stand on this platform, and if the soil was at all tough, one or two more men would add their weight. Upon reaching the proper place on the embankment the driver would step off the platform and the scraper would flop over or dump automatically. A buck scraper of this size requires four horses to pull it. The material is not carried by any scoop or bowl as with the drag scraper, but is pushed or "drifted" along in front of the blade. The modern road machine in which the blade is supported by a framework carried by four wagon wheels is a development of the buck scraper. So also are the smaller leveling scraper and the Shuart grader. The Shuart grader has a steel blade about 6 ft. long and 16 ins. high, mounted on a framework in front of a small platform. Two very small wheels behind and a small castor wheel in front serve to support this frame work. The blade is raised and lowered by means of a rack and pinion operated by a man standing on the rear platform, where the driver stands also. The writer is quite familiar with the work of the leveling scraper and the Shuart grader, but has used them largely to level embankments rather than to move earth any considerable distance.

Mr. Geo. J. Specht, to whose paper on earth work

reference was made in Chapter I, used buck scrapers in moving very large quantities of earth in building levels and in digging small canals in California in 1882 to 1884. His records of cost are the most complete to be found in print, so will now be given. Horses were hired by the contractors at 37½ cts. to 50 cts. per day per head, and feed cost 35 to 40 cts. Chinamen were employed as common laborers at $1.15 per day, and white laborers as drivers, etc., received the same plus their board, which cost 40 cts. a day for food alone. Although most of the soil was sandy loam, four to eight horses were hitched to a plow with one driver and one man holding plow. For the sake of uniformity with other data in this book we shall assume that each laborer received $1.50 and each horse $1.00 per day of 9 hours, for while we ordinarily shall use the 10-hr. day, it seems that in this particular case the men and teams worked with such vigor their output was as great as could ordinarily be obtained in 10 hours.

On the Upper San Joaquin Irrigating Canal, which was cut into a steep side hill, the buck scrapers with four horses attached traveled 400 ft. in making a round trip, and went loaded down a slope of about 1 in 4, returning uphill empty—an unusually favorable condition. Mr. Specht says that 95 round trips were made in 9 hrs. by each buck scraper, and as the result of a great many observations he found the average load to be 1.3 cu. yds., although as high as 1.64 cu. yds, in one case. He gives 128 cu. yds. as the average daily output of each buck scraper. It should be observed, however, that the material was all pushed down a very steep hill. From the foregoing it appears that it took 5⅝ minutes to make a round trip of 400 ft., which is equivalent to a speed of 70 ft. a minute, including stops. This is so extraordinarily slow that we are very much inclined to believe that the actual speed was greater, but that each load was very much smaller

than given by Mr. Specht. Mr. Specht gives the following data:

COST FOR NOVEMBER, 1882; 27½ DAYS' WORKED.

| | | | |
|---|---|---|---|
| 6-horse plow (with 2 men) .......... | 29½ days | at $9.00 | $265.50 |
| 4-horse plow (with 2 men)........... | 15½ " | " 7.00 | 108.50 |
| 4-horse buck scraper (with 1 man).. | 409 " | " 5.50 | 2,249.50 |
| 2-horse drag scraper (with 1 man).. | 130½ " | " 3.50 | 456.75 |
| White man on dump ................ | 33 " | " 1.50 | 49.50 |
| Chinese laborers. .................. | 328 " | " 1.50 | 492.00 |
| Chinese bosses ..................... | 18 " | " 2.00 | 36.00 |
| | | | $3,657.75 |
| General expenses (foreman, bookkeeper, blacksmith and hostler)........... | | | 300.00 |
| 55,925 cu. yds. excavated at 7 cts. .................... | | | $3,957.75 |

Note.—The drag scrapers were used to bring part of the material up from the bed of the canal and deliver it to the buck scrapers; and in doing this, where the round trip traveled by a drag scraper was 225 ft., the output of each drag was 18 cu. yds. in 9 hrs., which, it should be observed, was an exceedingly low output. Deducting material moved by drags, we see that still each buck scraper moved 130 cu. yds. in 9 hrs.

The foregoing was for November, 1882, but the following January, 42,241 cu. yds. were moved in 22 days at about the same rate, although there was a cost of about ½ ct. more per cu. yd. for plowing and 1½ ct. more per cu. yd. for additional Chinese labor, presumably for grubbing roots and trimming slopes, although not so stated.

In February some hardpan was encountered, adding still another 1½ cts. per cu. yd. for powder, etc., distributed over the 80,000 cu. yds. moved that month.

In the year of 1884, Mr. Specht built the levees described in Chapter I., which description need not be repeated here. Material was largely sandy loam with some adobe, and the "lead" was about 70 ft.; 90% of the material was drifted up a 1 in 4 slope, using buck scrapers. The first 70,000 cu. yds. was moved at the rate of 55 cu. yds. a day per buck scraper; the slow rate being due largely to inexperience of contractors. Later the same contractors moved 294,000 cu. yds. at the rate of 90½

cu. yds. per buck scraper a day. The first month, when the levee embankments were being started, the cost was about 10 cts. per cu. yd., but the second month, when the levees had grown higher, the cost was about 12 cts. per cu. yd. The rent and feed of horses we have assumed at $1 a day, and wages of labor and board at $1.50; but Mr. Specht fails to state the number of men and rate of wages, giving sum totals only, and we may be slightly in error in making this last assumption.

COST WITH DRAG SCRAPERS.—A drag scraper, or scoop, or "slip," or "slusser" is a steel scoop, not mounted on wheels, for scooping up and transporting earth short distances, and is drawn by a team. Occasionally a small scraper drawn by one horse is used, but not so economically. The ordinary No. 2 "drag" weighs about 100 lbs. and can be pulled full up a 3 to 1 slope. While the listed capacity in some catalogues is as high as 7 cu. ft. for a No. 1 and in others at 5½ cu. ft., and for a No. 2, 4½ to 5 cu. ft., actual measurement will quickly show that such listed capacities are excessive, except upon the assumption that the scraper is heaping full; and even then it should be remembered that the earth is loose, and about 20% must be subtracted from the loose volume to get measurement in cut. Trautwine overlooked the shrinkage item and assumed the listed capacities to be correct. Of course, many of the loads, even in ordinary soil, are not full loads; and frequently in stony or rooty soil the load is lost by accidental dumping before the embankment is reached. Trautwine's table of cost is based on loads of $^1/_5$ cu. yd. place measure (which is about double the actual average), and he estimates a speed of 150 ft. a minute with 15 ft. added to the lead for turning around—altogether too small an allowance for short leads. The actual speed is about 220 ft. a minute, and the lost time in loading and dumping (which Trautwine entirely overlooks)

is $\frac{1}{3}$ to $\frac{1}{2}$ a minute. As evidence conclusive of the falsity of Trautwine's assumptions we need but call attention to the fact that it is utterly impossible to move 220 cu. yds. in 10 hrs. with one scraper as given in his tables on a 40-ft. "lead." The author has never seen an average of one-third that amount maintained, and his records of cost of moving 60,000 cu. yds. of "easy gravel" (little plowing required) show that the average output per scraper was 62 cu. yds. in 10 hrs. with a lead of 50 ft. and embankment 8 ft. above bottom of pit. Under the same conditions where stiff clay was moved the output was 40 cu. yds. in 10 hrs. per scraper, where 20,000 cu. yds. were moved.

Morris, whom Trautwine copied in part, found the average capacity of the wooden scraper used in his day (1841) to be $^1/_{10}$ cu. yd. place measure, and he allowed $1\frac{1}{3}$ min. lost time in loading and turning out each round trip, and assumed a speed of 140 ft. a minute. The author's experience agrees with his in all but the speed, which the author finds to be 50% greater. It is a very easy matter to err in estimates of speed on short hauls, where teams are continually stopping for one thing or another. While actually walking, unless the drivers loaf, the speed of scrapers is almost as great as wagons. In working drag scrapers on the ordinary short leads there are usually 3 teams traveling in a circle or ellipse of about 150 ft. circumference, so that each team has about 50 ft. to itself, which is none too much. One man loads the scrapers as they go by, and each driver dumps his own scraper. It is evident that with a "lead" of only 25 ft., the actual haul from pit to dump is 75 ft., yet for a lead of 25 ft., Trautwine assumed the absurdly low allowance of 15 ft. more, instead of 50 ft. for manœuvering the teams. The actual loads of drag scrapers average for tough clay $^1/_{10}$ cu. yd., for gravel $^1/_7$ cu. yd., and for loam $^1/_5$ cu. yd.

Bearing out the author's experience may be cited that of Mr. J. M. Brown already referred to.

In building a railroad embankment (Iowa) 2 ft. high, 20 ft. wide at the base, the distance from the center of the borrow pits at the side to the center of the fill was 33 ft. Large drag scrapers holding 4 cu. ft. of earth when full but 3 cu. ft. of $^1/_9$ cu. yd. on an average were used. Each team made a trip in 1½ minutes, and 60 cu. yds. moved per scraper was a good 10-hrs. work.

One plow was used requiring at times one team, at times two teams (average 1½ teams), loosened 360 cu. yds. in 10 hrs. One man to every two scrapers was required to load them, and one man to every six scrapers to dump them. There was one foreman to each of these gangs. [N. B.—The author's experience has generally been that one man is needed to load these scrapers, and no man is required to dump them, the driver doing that; but it is generally well to figure in another man to every three teams to be used in grubbing small roots, etc.] Thus with a 33-ft. "lead" Mr. Brown's experience was that, including foreman, it costs 10 cts. per cu. yd., wages being 15 and 35 cts. per hour for men and teams respectively. To this he recommends adding 3 cts. for each added 33 ft. of "lead" which is erroneous, the error arising from his failure to see that the "lost team time" in loading and dumping is no more for a lead of 100 ft. than for a lead of 33 ft.

In diking several miles of a creek the writer kept careful record of the cost of excavating 55,500 cu. yds. of sandy gravel measured in cut taken from the bottom of the dry creek bed. This material was excavated by 1,040 team days (with driver) and 900 man-days of 10 hours each, at a total cost of $5,000, wages being $3.50 a day for teams and $1.50 for men, which is equivalent to 9 cts. per cu. yd. Drag scrapers were used, three in a "string" traveling in a circle about 150 ft. around, although the "lead" was but 50 ft. The bottom of the creek was 50 ft. wide and excavated to a depth of about 2 ft., the material being placed in dikes on each side, the

top of the finished dike being 9 ft. above the bottom of the finished channel. About 5 acres of brush were cleared from the banks, but not grubbed. There was one scraper holder to each string of three teams, and one plow team to every 6 or 7 scrapers. Each scraper averaged 62 cu. yds. excavated per day, so that each plow averaged about 400 cu. yds. per day, and including plow teams the average output per team was 53 cu. yds. per day.

In diking another creek the material encountered was a rather stiff clay which was plowed with a heavy single team. The finished channel in this case was only 15 ft. wide at bottom, and the top of the finished dikes was 6 ft. above the bottom of the channel. The "lead" was only 20 ft., but the teams traveled as in the preceding case, three in a string, describing a circle or ellipse 150 ft. in circumference. With 540 team-days (including driver) and 620 man-days, wages as before, 20,100 cu. yds. were moved at a cost of $15^5/_8$ cts. per cu. yd., $4\frac{2}{3}$ cts. being for labor and $9^1/_6$ cts. for teams. To this was added $\frac{1}{2}$ ct. for tools, $\frac{1}{2}$ ct. for sundry expenses, and 3 cts. per cu. yd. for foremen, making a grand total of $17^5/_6$ cts. per cu. yd. The foreman item would not ordinarily exceed 1 ct. per cu. yd., but in this case frequent rainy spells flooded the creek bed and stopped work, during which time the foreman's pay went on. Not including plow teams, the output per drag scraper team was 37 cu. yds. per day. The very same gang later, under another and better foreman, moved 15,000 cu. yds. of clay, at the rate of 48 cu. yds. per scraper per day, and including plow teams, of which there was one to every six scrapers, the output was 38 cu. yds. per team-day of 10 hrs. There were 8 men, beside drivers, for every 10 teams, so that the cost was $9\frac{1}{4}$ cts. per cu. yd. for team work, $3^1/_6$ cts. for labor, 1 ct. for foreman, and $\frac{1}{2}$ ct. for tools and sundries, making a total of nearly 14 cts. per cu. yd. We believe that it would be difficult to

better this output in stiff clay, for the horses and men all worked with energy.

In excavating 2,100 cu. yds. of gravel in a road cut to a depth of about 32 ins., the top 8 ins. being frozen, 12 men and 8 teams on drag scrapers and plow were engaged 6 days of 10 hrs. The haul was 50 to 75 ft. The output was 50 cu. yds. per scraper-day, and 44 cu. yds., per team-day, including plow teams.

Based upon the author's experience we have the following:

RULE IV.—To find the cost per cu. yd. of average earth moved with drag scrapers, add together the following items:

$^1/_{20}$-hour's wages of team with driver and plowman for plowing.

$^1/_{10}$-hour's wages of team with driver and plowman, lost time loading, etc.

$^1/_{20}$-hour's wages of laborer loading scrapers.

$^1/_{9}$-hour's wages of team with driver for each 100 ft. of haul, assuming no haul ever less than 75 ft. to allow for turning and manœuvering teams.

With wages at 15 cts. per hour for labor and 35 cts. for team with driver this rule becomes: To a fixed cost of 6 cts. per cu. yd. add 4 cts. for each 100 ft. of haul, assuming no haul ever less than 75 ft. Fairly tough clay, hard to load will cost one-third more.

## CHAPTER VIII.

### Cost by Wheel Scrapers.

What was stated in Chapter VII. regarding catalogue listed capacities of drag scrapers as compared with actual averages applies also to wheelers.

The following has been taken from catalogues, excepting the last two columns, that the author has added:

| Size of wheeler, No. | Bowl: Depth in ins. | Width in ins. | Length in ins. | Weight of wheeler in lbs. | Catalogue capacity cu. ft. | Actual struck measure, cu. ft. of loose earth. | *Actual place measure. |
|---|---|---|---|---|---|---|---|
| 1. | 12 | 36 | 36—36 | 340—450 | 9—10 | 7½—9 | 6—7⅕ |
| 2. | 12—13½ | 38 | 33—37 | 475—500 | 12—13 | 8¾— | 7— |
| 2½. | 13½ | 38 | 41 | 575 | 14 | 12⅙ | 9.7 |
| 3. | 16 | 42—44 | 40—41 | 625—800 | 16—17 | 15½ | 12.4 |

*Actual place measure, capacity 20% less than loose measure.

Large wheel scrapers, even in light soils, and small wheelers in tough soils seldom leave the pit full of earth, but at the back end of the bowl there is usually a wedge-shaped space unfilled where the earth slopes up from the bottom of the pan on a 1½ to 1 slope. Unless front end gates are used on large scrapers, a similar unfilled space exists at the front end of the bowl, before the team has traveled far, thus reducing the capacities given in last column by 2 to 3 cu. ft. The author has found the average load (place measure) carried by wheelers is as follows: No. 1, $^1/_5$ cu. yd.; No. 2, ¼ cu. yd.; No. 2½, ⅓ cu. yd.; No. 3, $^4/_{10}$ cu. yd.

These loads, however, can be materially increased by the simple expedient of having men with shovels to fill the bowl heaping full when the soil is such that the team cannot fill the bowl. The longer the haul, of course, the better it will pay to so fill the bowl.

A snatch team is generally used with a No. 2 wheeler and always with a No. 3, to assist in load-

ing, but even with a snatch team it is impossible to fill the bowl in tough clay. In such cases by all means use shovelers.

Wheel scrapers had not been invented in the day of Elwood Morris, so that Trautwine's tables form the only published attempt to analyze the cost of moving earth by wheelers. Since Trautwine assumes the catalogue listed capacity of wheelers as being correct, and furthermore makes no reduction for the shrinkage of loose earth, his tables are obviously erroneous. Moreover, he allows only 25 ft. of "lead" for turning around, and makes no allowance for time lost in loading and dumping. As a result of these inaccuracies his tables indicate that, with a 40-ft. "lead" one wheeler can move 200 cu. yds. in 10 hrs.! It is needless to say that such a record is impossible of performance.

With wheelers, as with drag scrapers, add 50 ft. to the actual "lead" for turning and manœuvering the teams, equivalent to ½ minute of team time each trip. Another ½ minute is lost in loading and dumping, and still another ½ minute helping load the scrapers.

The lightest No. 1 wheelers made are to be recommended where leads are very short and rises steep, that is wherever drag scrapers are ordinarily used, for they move earth more economically than drags. Where soil is very stony, or full of roots, drag scrapers are to be preferred, since they are more easily and quickly loaded under such conditions.

The method of handling No. 1 wheelers is the same as that above given for drags.

To substantiate what the writer has said as to Trautwine's errors, it may be well to give the published experience of others as to the actual work done with wheel scrapers.

As giving what is probably a maximum cost we may cite again the Forbes Hill Reservoir, referred to in Chapter IV. The material was clay-gravel or hardpan requiring two teams on a pavement plow.

A snap or snatch team was used in loading the No. 3 wheelers, two men holding the scraper handles. The haul was 250 to 300 ft. "The wheel scrapers theoretically held ¾ cu. yd., but in the material here excavated only about ⅜ cu. yd. could be readily loaded automatically. Under favorable conditions each team averaged 35 cu. yds. per day (of 9 hours?), making 8 to 10 trips per hour." With labor at 15 to 17 cts. and teams at 45 to 50 cts. per hour, the cost of excavating nearly 16,000 cu. yds. of hardpan was:

| | Per cu. yd. | |
|---|---|---|
| Plowing | 10.9 | cts. |
| Scraping | 22.2 | " |
| Unloading and spreading carefully | 7.7 | " |
| Rolling | 3.9 | " |
| Total | 44.7 | " |

The cost of stripping 8,700 cu. yds. of loam and transporting to a spoil bank, haul not given but presumably about the same, was:

| | Per cu. yd. | |
|---|---|---|
| Plowing | 3.4 | cts. |
| Scraping | 14.0 | " |
| Unloading | 0.6 | " |
| Total | 18.0 | " |

Bearing in mind that wages were high (45 to 50 cts. per hour of team time) the cost was nevertheless considerably above the ordinary.

Mr. J. M. Brown's experience (see Chapter VI.) has led him to state that only No. 1 and No. 3 wheelers should be used. The author cannot agree with him, believing that No. 2 is the best size for all around work. The following has been abstracted from Mr. Brown's paper, reference to which will be found in Chapter VI.

A No. 1 wheeler holds ¼ cu. yd. of earth (Iowa) on an average, and one trip in 2 to 2½ minutes is the average, where the haul is 100 ft., thus giving

an output of 60 cu. yds. in 10 hours. With the following force, 1 plow, 6 wheelers, 3 loaders, 1 dumper, and 1 foreman, the cost was:

| | Per cu. yd. |
|---|---|
| Labor, loading, dumping, etc. | 4.11 cts. |
| Scraping (100 ft. haul) | 5.83 " |
| Wear of tools | 0.39 " |
| Total | 10.33 " |

With a 100-ft. haul, 6 wheelers; with a 200-ft. haul, 9 wheelers, and with a 300-ft. haul, 12 wheelers (No. 1) are required to move 360 cu. yds. in 10 hours, according to Mr. Brown, at an added cost of about 3 cts. per cu. yd. for each 100 ft. of haul. We believe this 3 cts. per 100 ft. to be erroneous for the same reasons given in the last chapter relating to drag scrapers; because Mr. Brown has made the average speed of the team too small by failure to subtract lost time at both ends of the haul.

Mr. Brown gives the following data for No. 3 wheelers; a snatch team and two men being used to load; 8 wheelers each moving 40 cu. yds. in 10 hours with a 400-ft. haul. With wages at 15 and 35 cts. we have:

| | Per cu. yd. |
|---|---|
| Plowing | 1.66 cts. |
| Holding scraper | 1.66 " |
| Dumpman | 0.50 " |
| Foreman | 0.70 " |
| Scraping (400-ft. haul) | 7.77 " |
| Wear of tools | 0.50 " |
| Total | 12.79 " |

Mr. Brown adds two wheelers for each 100 ft. of added haul, or 2 cts. per cu. yd. per 100-ft. haul, which, we repeat, is erroneous.

The most extensive and reliable data on wheel-scraper work are given in Hill's "Chicago Main

Drainage Canal."* Excellent papers on the same subject by Mr. A. E. Kastl and Mr. E. R. Shnable are to be found in the Journal of the Association of Engineering Societies, Vol. XIV., 1895. From these sources we have abstracted the following relative to costs on the Chicago Drainage Canal:

The soil moved by wheelers was a "fairly soft clayey loam," and the average haul was about 400 ft., the material being deposited in spoil banks.

On the Brighton Division, Section K, 68,300 cu. yds. were moved in 62 days, the average force being 23.8 men and 36.8 teams with drivers. There were two plows and 24 No. 3 wheelers in use, hence each plow loosened 550 cu. yds., and each wheeler moved 46.1 cu. yds. per 10-hour day; while the average output, including snatch teams of which there appear to have been about one for every three wheelers, and including plow teams, was about 30 cu. yds. per day per team.

For Summit Division, Section E, Mr. Shnable gives the following: The haul was 400 ft. The number of men engaged is not given, but we have assumed $\frac{2}{3}$ man per team, which is not far from right.

| Stations. | Average Fill, ft. | Average Cut, ft. | Total excavation, cu.yds. | Daily average, cu. yds. Per team. | Daily average, cu. yds. Per whlr. | Ratio of teams. Wheelers to plows. | Ratio of teams. Wheelers to team. | Cost, cts. per cu. yd.[1] |
|---|---|---|---|---|---|---|---|---|
| 460 to 470 | 12 | 8.0 | 94,879 | 29.8 | 42.2 | $5\frac{1}{3}$—1 | $4\frac{4}{10}$—1 | 15.1[2] |
| 470 " 480 | 12 | 8.3 | 98,515 | 27.1 | 39.3 | $4\frac{9}{10}$—1 | $4\frac{4}{10}$—1 | 16.6[2] |
| 480 " 490 | 11 | 7.0 | 85,761 | 24.4 | 35.2 | $4\frac{8}{10}$—1 | $4\frac{3}{10}$—1 | 18.4[2] |
| 490 " 500 | 7 | 3.4 | 33,185 | 35.0 | 50.1 | $4\frac{9}{10}$—1 | $4\frac{4}{10}$—1 | 12.9[3] |
| 500 " 507 | 7 | 4.3 | 29,678 | 28.3 | 42.1 | $4\frac{6}{10}$—1 | $3\frac{7}{10}$—1 | 15.9[4] |

[1]Assuming $\frac{2}{3}$ man per team.
Material: [2]Very stiff blue and yellow clay with a few large boulders. [3]Loamy clay. [4]Stiff clay.

The table shows that there were about five wheelers to each plow, hence each plow team must have loosened about 200 cu. yds. in 10 hours; the hardest section being from Sta. 480 to Sta. 490, where 168 cu. yds. was the average per plow team per day. Doubtless two teams were worked on

*Now out of print, but originally compiled from a series of articles appearing in Engineering News, 1895-6.

each plow. One snatch team to every 4.4 wheelers appears to have been the average, or each snatch team loaded about 175 cu. yds. a day at a cost of 2 cts. a cu. yd.

WHEELERS FOR LOADING WAGONS.—Wheel scrapers were used on the Chicago Drainage Canal for loading cars by dumping the earth through a platform into the cars (Hill, p. 14); and similar use of wheelers for loading wagons has been made elsewhere.

The incline approach to the platform need not rise with a less than 20% grade, and may have a width of 8 ft. instead of the 12 used on the Chicago Canal. The cost of such an incline (12 ft. wide by 120 ft. long including both approaches) is given at $100. It is not the first cost of the incline, but the cost of moving it that makes this method too expensive ordinarily; and the shallower the excavation the more frequent the moving of this incline. As an expedient to reduce this cost of moving the incline, the author would suggest that it be made with two wooden stringers (6-in. × 6-in.) under the sills of the bents and that these stringers which are to act like the runners of a sleigh be planed upon the bottom and rest upon cross ties or skids, placed like railroad ties, only farther apart, say 4 ft. c. to c., dressed on top and well greased. Make the flooring as light as possible, using a very small factor of safety, and make the incline in two detachable sections. Ten or a dozen teams will then readily "snake" the incline along over skids laid in advance, and it will be unnecessary to take the incline apart to move it. By study of the foregoing data it will appear that loading wagons by wheelers is some 3 cts. cheaper per cu. yd. than by shovels, so that if the cost of moving the incline is not great the method is a good one.

The following rules of cost by wheelers are based upon careful timing of individual teams checked by large excavations, one of 20,000 cu.

yds. at Elmira, N. Y., and another of equal size near Brighton, N. Y., beside several smaller jobs under the writer's directions. The rules, moreover, will be found to agree closely with all published data where conditions have been similar.

RULE V.—To find the cost per cu. yd. of average earth moved with No. 1 wheel scrapers ($^1/_5$ cu. yd. load), add together the following items:

$^1/_{20}$-hour's wages of team with driver for plowing;
$^1/_{12}$-hour's wages of team with driver, "lost time" loading;
$^1/_{15}$-hour's wages of man loading scraper;

then add $^1/_{13}$-hour's wages of team with driver for each 100 ft. of haul, assuming no haul less than 75 ft. With wages at 15 cts. per hour for men and 35 cts. for team with driver the rule becomes: To a fixed cost of 6 cts. per cu. yd. add $2\frac{3}{4}$ cts. per cu. yd. for each 100 ft. of haul.

RULE VI.—To find the cost per cu. yd. of average earth moved with No. 2 wheel scrapers ($\frac{1}{4}$ cu. yd. load), using no snatch team, add together these items:

$^1/_{20}$-hour's wages of team with driver for plowing;
$^1/_{15}$-hour's wages of team with driver for "lost time" loading, etc.;
$^1/_{15}$-hour's wages of man loading scrapers;
$^1/_{15}$-hour's wages of man dumping scrapers;

then add $^1/_{16}$-hour's wages of team with driver for each 100 ft. of haul, assuming no haul ever less than 75 ft. With wages at 15 cts. per hour for men, and 35 cts. for team with driver this rules becomes: To a fixed cost of 7 cts. add $2\,^1/_5$ cts. per cu. yd. for each 100 ft. of haul, no haul ever less than 75 ft.; and if a snatch team is required to load add 2 cts. more per cu. yd.

RULE VII.—To find the cost per cu. yd. of average earth moved with No. 3 wheel scrapers

($^4/_{10}$ cu. yd. load), using a snatch team, add together the following items:

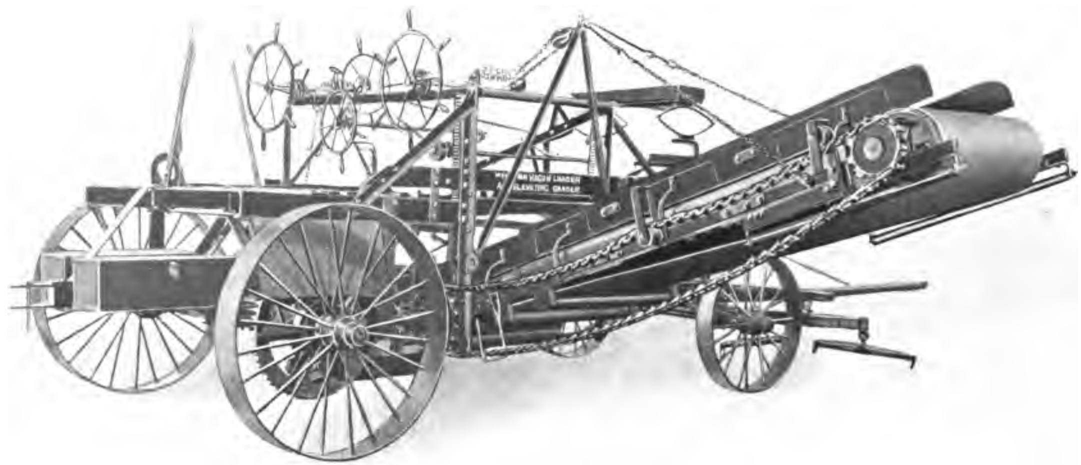
$^1/_{20}$-hour's wages of team with driver for plowing;
$^1/_{15}$-hour's wages of team with driver for "lost time";
$^1/_{18}$-hour's wages of team with driver for snatch team;
$^1/_{10}$-hour's wages of man loading scrapers;
$^1/_{20}$-hour's wages of man dumping scrapers;

then add $^1/_{30}$-hour's-wages of team with driver for each 100 ft. of haul. With wages at 15 cts. for men and 35 cts. for team with driver, this rule becomes: To a fixed cost of $8\frac{1}{3}$ cts. per cu. yd. add $1^1/_6$ cts. for each 100 ft. of haul, assuming no haul less than 100 ft.

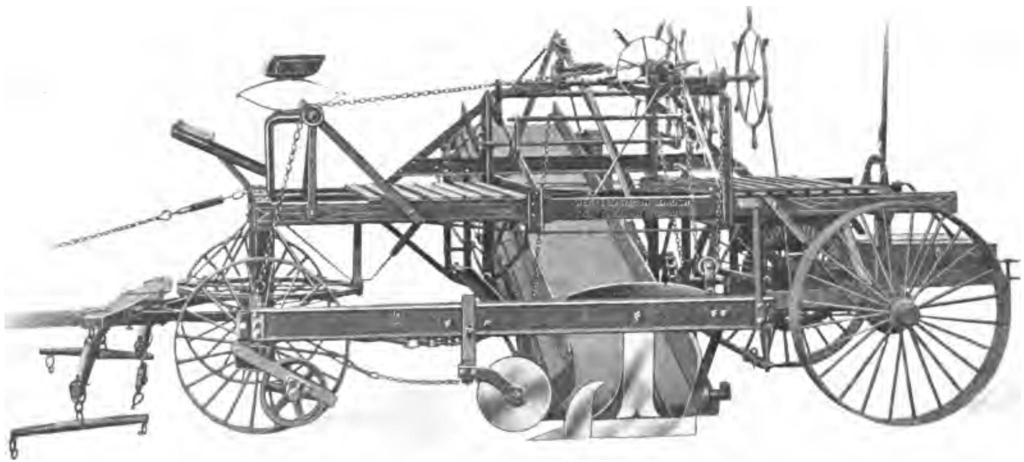
## CHAPTER IX.

### Cost by the Elevating Grader.

A description of the elevating grader need not be given since a letter to the manufacturers of either the New Era or the Western Grader will secure a catalogue. Suffice it to say that the grader consists of a plow casting a furrow upon a transversely traveling belt that elevates the earth, dumping it into wagons traveling alongside the grader. It is obvious that in sand or gravel, where a plow will not turn a good furrow, the elevating grader cannot be used. There must be few boulders or roots to stop the plow of the machine; and there must be considerable room in which to turn the machine, and manœuver the teams going and coming. The machine is not well adapted to loading wagons on road work, but is especially suitable for reservoir work and the like. The machine is used in prairie soils for digging ditches and carting the material directly into the road, but the material must afterward be leveled with a leveling scraper or road machine; and it would seem better practice to use the road scraper entirely for this class of grading without resort to the elevating grader at all. Manufacturers "guarantee" 1,000 cu. yds. in 10 hours loaded by the grader. The author, however, has never seen a daily average of more than 500 cu. yds. place measure loaded by a grader operating in easy soil at Corning, N. Y. Hill, p. 19, gives the following relative to moving fairly soft clayey loam of the Chicago Drainage Canal with the New Era grader and wagons, haul being 500 ft.: Section I, Septem-



Western Elevating Grader.



Western Elevating Grader.

ber, 485 cu. yds. per 10-hour day; Section K, August, 490; September, 515 cu. yds. per 10-hour day. The plant consisted of 7 wagons, 14 pairs of horses and 17 men and one grader. With wages at 15 cts. per hour for men and 20 cts. per hour for a pair of horses, we have $10\frac{3}{4}$ cts. labor cost of moving the earth 500 ft., as compared with 15 cts. (Chapter VIII.) by wheelers.

An elevating grader costs $1,000, and the seven large dump wagons, each requiring three horses to pull it, cost another $1,000. This $2,000 plant we may assume can be rented some years, and some it cannot, so that its owner may perhaps estimate using it or renting it for 60 working days annually. with interest and depreciation at 20%, we have about $7 as the charge to be made for each working day and ordinarily such a plant would be cheap at that price if rented. The cost of plant, therefore, adds about $1\frac{1}{2}$ cts. to each cu. yd. moved. Where the work is of great magnitude, the cost of the plant may be divided by the total number of cu. yds. to be moved with it, which is a common way of estimating work upon the part of contractors, although engineers frequently omit this item entirely, and err in so doing. Summing up we may put the cost of moving earth with elevating graders thus, assuming an output of 500 cu. yds. moved 500 ft. in 10 hours:

| | Cu. yd. |
|---|---|
| 5 Pairs of horses and 5 men........... | 3.5 cts. |
| 9 Pairs of horses and 6 men on 6 wagons. | 5.5 " |
| 5 Men on the dump and grubbing...... | 1.5 " |
| Total labor ......................... | 10.5 " |
| Plant, say...... .................. | 1.5 " |
| Total............................ | 12.0 " |

Due to the fact that room must be had in which to move the grader and the string of teams on the wagons, we are not safe in figuring on a haul of

less than 500 ft. no matter how short the "lead" actually may be.

Using three-horse patent dump wagons holding $1\frac{1}{4}$ cu. yds. place measure for hauling, an elevating grader with five teams and five drivers and helpers, and one man on the dump for every 100 cu. yds. delivered, we have:

RULE VIII.—To find the cost per cu. yd. of average earth loaded with an elevating grader and hauled with three-horse dump wagons, add together the following items:

$^1/_{10}$-hour's wages of a 2-horse team with driver for loading;
$^1/_9$-hour's wages of a 3-horse team with driver for "lost time";
$^1/_{10}$-hour's wages of man dumping;

then add $^1/_{80}$-hour's wages of a 3-horse team with driver for each 100 ft. of haul over 500 ft. With wages at 15 cts. for labor, 35 cts. for 2-horse team with driver, and 45 cts. per hour for 3-horse team with driver, this rule becomes: To a fixed cost of 10 cts. per cu. yd. for all hauls under 500 ft. (corresponding to a "lead" of 200 ft.), add $^{45}/_{80}$ ct. for each additional 100-ft. haul.

The writer kept the following records of cost, using a 25 HP. traction engine for hauling the elevating grader. Soil was easily plowed earth taken from "pits" alongside the railroad fill. The crew was one engineman, two men operating the elevating grader, one team on water tank, nine two-horse patent dump wagons, four men on dump spreading, one water boy and one foreman. The "lead" was only 100 ft. The grader traveled 600 ft., in which distance it loaded 15 wagons and then turned around, the turn taking 1 to 2 mins. Each wagon had about 1 cu. yd. of loose earth, equivalent to about 0.7 cu. yd. in "cut," and 700 wagons were loaded per 10-hr. day. It took about 15 secs. to load a wagon (the grader traveling about 150

New Era Graders Loading Wagons.

ft. per min.), then the grader stopped for 15 secs. until the next wagon came up into place. It required a width of about 50 ft. in which to turn the grader and engine. Six three-horse wagons would have served much better than the nine two-horse wagons used.

## CHAPTER X.

### Cost by Steam Shovels.

For loading earth, the steam-shovel method is far and away cheaper than any other, where it can be used. The shovel, however, is a tool of comparatively limited applicability, since it requires a cut of some considerable depth so as to have a face into which the shovel may dig; and the yardage to be moved must be great enough to pay for installing the plant, and for moving the shovel. A shovel with 1 to 1½-cu. yd. dipper appears to be the best for ordinary purposes.

Manufacturers frequently "guarantee" enormous outputs for their shovels, as high as 3,000 cu. yds. in ten hours; but it should be stated that such outputs are based upon loose measure of earth and upon the assumption that the shovel is working steadily in easy soil without any of the necessary delays due to moving away full cars, and bringing up the empties, and without counting the time lost in moving the shovel itself, and time lost in breakdowns, etc.

"On the Manchester Canal, in England, the steam shovels averaged 70 cu. yds. in light soil, and 45 cu. yds. per hour in clay." The following tabulated outputs are taken from the pages of Engineering News, 1895-6.

The material was a tough clay that in many cases had to be blasted.

SUMMIT DIVISION; CHICAGO CANAL.

| Section. | Shovel used. | General average cu. yds., 10 hours per shovel. | |
|---|---|---|---|
| A. | "Vulcan," shoveling into 5-cu. yd. cars.. | 600 | |
| B. | Two shovels(?), into large and small cars | 490 | for 5 mos. |
| C. | Two "Barnhart AA," into small cars.... | 350 | " 1 mo. |
| C. | Two "Barnhart AA," into large cars..... | 490 | " 1 " |
| D. | Two "Bucyrus No. 0 Boom," large cars.. | 600 | " 9 mos. |
| D. | Two "Bucyrus No. 0 Boom," into cars.. | 820 | " 1 mo. |
| D. | Two "Bucyrus No. 0 Boom," into wagons | 500 | " 1 " |
| E. | Two "Barnhart AA," into large cars.... | 510 | |

SUMMIT DIVISION—(Continued).

| | | | |
|---|---|---|---|
| F. | Two "Barnhart AA," small conveyor cars | 380 | " 5 " |
| F. | Two Bucyrus, into large cars .......... | 350 | |
| I. | Four shovels(?) into small cars........ | 660 | " 7 " |
| K. | Four shovels(?), into small cars........ | 670 | " 7 " |
| L. | Two Barnhart AA, ....................<br>Two Bucyrus No. 0 Boom ............ | 770 | " 9 " |
| M. | Two Barnhart AA......................<br>Two Bucyrus No. 0 Boom............. | 730 | " 9 " |
| 1. | Four Bucyrus Specials, into small cars.. | 280 | " 1 mo. |
| 1. | Four Bucyrus Specials, into large cars... | 495 | " 1 " |
| 1. | Four Bucyrus Specials, large & small cars | 455 | " 3 mos. |

LAMONT DIVISION.

| | | | |
|---|---|---|---|
| 2. | Two Osgood, into 3-cu. yd. cars........ | 370 | for 1 mo. |
| 2. | One Bucyrus No. 1 Boom............... | 630 | " 1 " |
| 2. | Two Osgood and One Bucyrus........... | 415 | |
| 3. | One Victor, into 3-cu. yd. cars.......... | 380 | " 8 mos. |
| 4. | One 70-ton Osgood, into 3-cu. yd. cars... | 406 | " 1 mo. |
| | Three Bucyrus No. 1 Boom.............. | 566 | " 1 " |
| | One Osgood and three Bucyrus.......... | 490 | " season. |
| 5. | Two Bucyrus and one Barnhart, into 1½ and 3-cu. yd. cars .................. | 380 | " 3 mos. |

While it is not stated what is meant by the term "small cars," 1½-cu. yd. cars are probably meant, and "large cars" are 3 to 5 cu. yds. capacity. The greatly increased output of a shovel where large cars are used is especially noteworthy, showing conclusively that the lost shovel time during the shifting of trains of cars is a very large item.

We may safely say that a shovel will load 50% more earth per day into 3-cu. yd. cars than into 1½-cu. yd. cars; so that in stiff clay the output of a shovel is about 360 cu. yds. per 10 hrs. loaded into small 1½-cu. yd. cars, and 500 cu. yds. into larger 3-cu. yd. cars, and 600 cu. yds. into 5-cu. yd. cars. As will appear in the next chapter, the method of handling cars has even more effect upon shovel output than the size of the individual cars. In cemented clay filled with boulders (hardpan) requiring blasting the output is about two-thirds as much as in stiff clay, while in gravel and easy soil generally one-third more earth can be daily loaded than in stiff clay.

The following will give a good idea of the forces used on shovel work on the Chicago Drainage Canal. On Summit Division, Section C, the plant consisted of:

2 Barnhart Special shovels;
4 Locomotives;

32 Large dump cars with boxes $1\frac{1}{2} \times 11\frac{2}{3} \times 12$ ft., struck measure capacity of $7\,{}^{7}/_{9}$ cu. yds.;
3 Centrifugal pumps and 1 dynamo;
$2\frac{1}{2}$ Miles of standard gage track.

The material was clay and hardpan. The output per 10-hour shift per shovel was: 762 cu. yds. in July; 533 cu. yds. in August; 820 cu. yds. in September; 493 cu. yds. in October; 503 in November, and 538 in December.

Two 10-hour shifts were worked each day except in December, when it was too cold to work nights, and the daily force was:

Force Excavating and Removing Material.

2 Foremen.
2 Cranesmen.
8 Pitmen.
4 Trainmen.
3 (to 12) Ditchers.
2 Shovel Enginemen.
2 Firemen.
4 Locomotive Enginemen.
18 (to 26) Dumpmen.
3 Men drilling and blasting.

Force Repairing Plant.*

1 Foreman.
1 Machinist.
2 Car repairers.
1 Blacksmith.
1 Blacksmith's helper.
12 Track Laborers.

Force Pumping and General Expense.

3 Pumpmen.
1 Swing team.
1 Timekeeper.
1 Superintendent.
1 Watchman.
1 Electrician.

On Section "F" the plant consisted of one "A" frame and two Bucyrus shovels, one Otis shovel,

*It is not stated whether this force worked one or two shifts each day—presumably one.

four large locomotives, three miles of standard gage track, three pumps and 30 Thatcher air dump cars, each holding 9 cu. yds. struck measure, the car weighing 17,600 lbs.

In clay the daily (10-hour) output per shovel was 732 cu. yds., or 1,464 cu. yds. output for two shovels, with a daily force distributed as follows:

Force Excavating and Removing Material.

2 Foremen.
2 Shovel Enginemen.
2 Cranesmen.
2 Firemen.
12 Pitmen.
4 Locomotive Enginemen.
4 Locomotive Firemen.
5 Trainmen.
25 Dumpmen.
2 Ditchers.
2 Water boys.

Force Repairing Plant.*

1 Foreman.
10 Trackmen.
1 Machinist.
1 Car Repairer.
1 Blacksmith.
1 Blacksmith's helper.

Force Pumping and General Expense Force.

3 Pumpmen.
1 Timekeeper.
1 Superintendent.
5 Watchmen.

In hardpan or boulder clay the plant was the same, except that due to the reduced output six less dump cars and one less locomotive were used. The output in hardpan was 440 cu. yds. per day per shovel. The force required was the same as in clay, except that one locomotive engineman, one fire-

*It is not stated whether this force worked one or two shifts each day—presumably one.

man and 13 dumpmen were dispensed with, but these were more than made up for by a new gang of 16 laborers and one foreman drilling and blasting the hardpan for the two shovels.

From an article in Engineering News, June 9, 1888, we take the following relating to the cost of shovel work on the Indianapolis, Decatur & Springfield R. R.

An Otis shovel was used. The haul averaged 4,000 ft. Twelve flat cars each holding 8 cu. yds. (N. B.—probably loose measure, but not stated) constituted a train, and were dumped with a plow and cable, at first in 15 minutes' time, later in 5 or 6 minutes; and the following table gives cost:

| | | | Trestle at | | |
|---|---|---|---|---|---|
| Place. | Sangamon River Trestle. | Montezuma Gravel Pit. | Sangamon River. | Guion. | Nichol's Hollow. |
| Year | 1885. | 1886. | 1886. | 1887. | 1887. |
| Days' worked | 46 | 115 | 38 | 85 | 40 |
| Days' idle | 0 | 45 | 3 | 7 | 4 |
| Material | Light clay | Gravel. | Light clay | Light clay | Light clay |
| Height, bank, ft. | 10 | 12 | 10 | 10 | 12 |
| Total cars loaded | 2,899 | 8,631 | 2,771 | 5,254 | 2,528 |
| No. cars per day: | | | | | |
| Greatest | 94 | 124 | 90 | 80 | 75 |
| Least | 22 | 16 | 50 | 30 | 15 |
| Average | 63 | 75 | 73 | 61.8 | 63.2 |
| Average haul | 1 mile. | 9 miles | 1 mile. | 2 miles. | ¾-mile. |
| Tons coal used: Shovel and locomotive | 141 | 853 | 99 | 170 | 65 |
| COST PER CARLOAD. | | | | | |
| Per day. | | | | | |
| Foreman ..$1.25 | $0.0886 | $0.0967 | $0.0800 | $0.0901 | $0.0988 |
| Craneman . 2.25 | .0535 | .0562 | .0480 | .0354 | .0557 |
| Fireman ... 1.50 | .0288 | .0337 | .0287 | .0290 | .0327 |
| 4 laborers . 1.25 | .0786 | .0992 | .0877 | .0980 | .0980 |
| Watchman . 1.00 | .0207 | .0196 | .0188 | .0250 | .0225 |
| Tot'l shovel crew | $0.2702 | $0.3054 | $0.2632 | $0.2775 | $0.3077 |
| Engineer and fireman. | | | | | |
| Conductor .$2.50 | 0597 | .1460 | .0574 | .0525 | .0577 |
| Brakeman.. 1.50 | | | | | |
| Train crew | .1797 | .2910 | .1318 | .1625 | .1887 |
| Helpers' distrib-ut'g earth $1.10 | ..... | .0174 | ..... | ..... | .0272 |
| Sec. trkmen 1.10 | .0081 | .0188 | .0138 | .0145 | ..... |
| Carpenters*. 2.50 | .0015 | .0220 | .0016 | .0104 | .0208 |
| Coal $1.25—1.40† | .0631 | .1330 | .0447 | .0431 | .0328 |
| Oil, waste, etc... | .0052 | .0155 | .0075 | .0046 | .0036 |
| Shop bills* | .0169 | .1090 | .0127 | .1060 | .0167 |
| Grand total.... | $0 5447 | $0.9119 | $0.4753 | $0.6226 | $0.5975 |
| Cost. per cu. yd.. | 0.0643 | 0.1140 | 0.0594 | 0.0779 | 0.0747 |

*For repairs. †Per ton.

It will be seen upon studying the foregoing table that 62 to 73 carloads of earth were excavated per average day worked, although on the best day 124 cars were loaded. Unfortunately there is nothing to show how the assumed carload of 8 cu. yds. was determined. If the earth was measured loose on the cars, as seems probable, each car held about 6½ cu. yds. place measure. If the cars held 8 cu. yds. the average daily output of the shovel ranged from 500 to 600 cu. yds; if the carload was 6½ cu. yds. place measure the daily output was 400 to 500 cu. yds.

Where the haul was ¾ mile to 2 miles the coal consumption of both shovel and locomotive was 1½ to 3 tons per day worked. When the haul was 9 miles, more than 7 tons of coal were daily consumed.

The cost of labor of the shovel crew was quite uniformly 28 cts. per car loaded, which is 3½ cts. per cu. yd. if each car held 8 cu. yds., or 4.3 cts. per cu. yd. if the cars averaged 6½ cu. yds. each.

The following data are from the writer's records of steam shovel work:

Data: A 35-ton Vulcan shovel, 1 cu. yd. dipper, traction wheels; 6 dump cars weighing 2,500 lbs. each, nominal capacity 3 cu. yds. each; 1 contractor's locomotive, 36-in. gage; 35-lb. rails on ties 6 × 6 ins. × 5 ft. spaced 4 ft. c. to c.; material excavated, 3 ft. of clay overlying 13 ft. of soft shale; haul 1,000 ft.; embankment, 40 ft. high; trestle made of two 42-ft. posts of round timber in each bent; 1 upright boiler and pump; coal consumption, 400 lbs. for pumping; 500 lbs. for locomotive and 1,700 lbs. for shovel per 10-hr. day.

| | Daily expenses. | Cost, per cu. yd. |
|---|---|---|
| 1 Foreman, per 10-hr. day | $4.00 | $0.008 |
| 1 Engineman | 3.00 | .006 |
| 1 Craneman | 3.00 | .006 |
| 1 Fireman | 2.00 | .004 |
| 3 Pitmen | 4.50 | .009 |
| 4 Drillers 4 10-ft. holes, 10 hrs.) | 6.00 | .012 |
| Total pit force | $22.50 | $0.045 |

| | | | |
|---|---|---|---|
| 1 | Locomotive driver | $3.00 | $0.006 |
| 1 | Trainman | 2.00 | .004 |
| 2 | Dumpmen | 3.00 | .006 |
| 1 | Engine and pumpman | 2.50 | .005 |
| | Total force | $33.00 | $0.066 |
| 300 | lbs. of black powder | 15.00 | .030 |
| 60 | lbs. of 40% giant powder | 7.50 | .015 |
| 1⅓ | tons coal at $3.00, delivered | 4,00 | .008 |
| | Oil, waste, etc. | 1.00 | .002 |
| | Total daily operating expense | $60.50 | $0.121 |

Where the bank was but 10 ft. high, 4 drillers instead of 6 were used, and no dynamite except 1½ sticks in each hole as a "squib" to make room for the 3 cans (25 lbs. each) of black powder. Three men dumping a car at a time take 3 mins. to dump a 6-car train; it takes 1 min. each way for making an 800-ft. trip, and 10 mins. to load the train of 6 cars, thus making 4 round trips an hour with about 12½ cu. yds. (solid measure) per trip. At first sight this method of using only one locomotive and one train seems very injudicious and wasteful of the time of the steam shovel which is idle during 5 minutes out of every 15. Where the bank is 10 ft. or less high, there is, however, little time actually lost; for the shovel is moved forward about 4 ft. at a time, and with a face 10 ft. deep × 15 ft. wide, it is evident that the shovel must be moved about every other train trip. Since it takes 3 to 5 mins. to move the shovel forward, it will be seen that there is really about 2½ mins. instead of the apparent 5 mins. lost each trip. Where the bank is higher, the haul longer, and especially where the shovel is a more powerful one, it does not pay to work with less than two locomotives: or two hoisting engines if the haul is short and cables are used to move the cars.

The method of using a hoisting engine and cable to move the cars is quite common in railroad work, where the hauls are short, say 1,000 ft. or less. The track is laid on a rather steep grade at least 3% from the pit to the dump and the cars coast down by gravity usually in trains of 4 cars holding about 2 cu. yds. each. The hoisting engines pull the cars

back with a wire rope. A team of horses will have all it can do to pull a train of four such loaded cars on the level (see next chapter.)

Where a large 65-ton steam shovel was used in railroad excavation similar to the foregoing it took 4 weeks with the full crew (above given) to move the shovel from the railway station to the cut a distance of 6 miles; and 3 weeks to move the same shovel down across a valley from a finished cut to a new cut on the opposite side a distance of ¼ mile. The cost of moving a 65-ton shovel one mile on a country road with heavy grades, and ½ mile through fields with 15° slopes was:

| | |
|---|---|
| 1 Shovel crew 8 days | $160 |
| 8 Men " " | 96 |
| 1 Team " " | 32 |
| 1 Foreman " " | 28 |
| Total for 1½ miles | $316 |

As compared with this great cost of moving a 65-ton shovel the following cost of moving a 35-ton traction shovel is noteworthy: The distance moved was 18 miles and the time occupied was 18 days by a crew whose wages were $35 a day. All but the last mile of moving was over rough roads, the last mile being across fields and up hill. The smaller traction shovel, it will be seen, can be moved in days where it takes weeks to move the larger shovel. In view of the ease of moving a smaller shovel the writer favors such shovels for general contracting work.

Summing up we may say, as to the cost of steam shovel work, that the average daily (10-hr.) expenses of loading loose gravel and material that readily caves is as follows:

| | |
|---|---|
| 1 Foreman | $4.00 |
| 1 Engineman | 4.00 |
| 1 Craneman | 3.50 |

| | |
|---|---|
| 1 Fireman | $2.00 |
| 4 Pitmen at $1.50 | 6.00 |
| Wages of shovel crew | $19.50 |
| 1 short ton of coal | 3.00 |
| Oil, waste, etc. | 1.00 |
| Water (1 gallon per lb. of coal), if pumped especially* | 3.50 |
| Total | $27.00 |

To this should be added annual interest and depreciation distributed over the actual number of days worked each year for a long series of years. In one instance given by Mr. Hermann the material for repairs to steam shovel, cars and locomotive was $460, and the labor item for repairs was $210, a total of $670 for six months' work in Iowa, which is equivalent to about $4.50 per working day. In addition to this a rental of $300 a month for the shovel and $250 a month were paid for a contractor's locomotive and cars.

When the harder material ordinarily excavated by shovels are encountered the force of pitmen must be increased by seldom less than 4 men, and often by many more as in the hardpan on the Chicago Canal above given. These extra men are required to break down the bank in front of the shovel, and powder is used liberally to this end, as above stated.

Ordinarily in work like that on the Chicago Canal, it pays to have two locomotives to each shovel; for while one locomotive can haul away all the earth excavated, evidently some means must be provided to "spot" the cars, that is to remove a full car and bring up an empty when the train is being loaded. If the track can be given a down grade of 2% for small dump cars the cars will move by gravity, no locomotive being required to spot the cars.

*Wages of pumpmen $2.50 + 1/8 ton coal.

Assuming 500 cu. yds. per 10-hr. shift as a fair shovel output for average earth, the actual cost of loading earth with a steam shovel is then $\frac{\$27.00}{500} = 5.4$ cts. per cu. yd., to which must be added interest and repairs to plant, cost of track laying and trestling. A shovel worth $6,000 @ 6% interest costs $360 a year for the interest item. Many contractors would estimate 15% interest, as they estimate that cash is worth that much to them in their business; and at that rate we should have $900 a year chargeable to interest. A steam shovel should be charged with not less than $5 per day actually worked for repairs and depreciation. Assuming $600 as a fair interest charge per annum, and 60 days actual working time each year for a long term of years, we have $10 per working day for interest plus $5 a day for repairs and depreciation. Then $\frac{\$15.00}{500} = 3$ cts. per cu. yd. chargeable to interest, repairs and depreciation, which, added to the labor and fuel item of 5.4 cts., makes a total of 8.4 cts. per cu. yd. for loading average earth with a steam shovel. In the next chapter will be given the cost of hauling by cars.

## CHAPTER XI.

### Cost by Cars.

In ordinary construction work dump cars ranging from 1 to 3 cu. yds. capacity are used where horses or contractor's locomotives furnish the tractive power. Such cars are generally run on light rails (16 to 40 lbs. to the yard) with ties wide spaced (4 ft. c. to c. usually) and not ballasted. To roughly lay such track with labor at 15 cts. per hour has cost the author about $2 per 100 ft. of track, or $100 per mile, after delivery of materials. The author has used 4 × 4-in. ties, but cannot recommend them, for after once using they are so split by the spikes as to be of little value. A 6 × 6-in. tie, 5 ft. long, is the best for general use on these narrow-gage roads.

Roughly laid as such track is, with light rails, and wide spacing of ties, it is not safe to estimate the rolling resistance at less than about 40 lbs. per ton of load on the car wheels (including the weight of car itself) on a level track.

It is very commonly stated that 20 lbs. is the force required to pull a 2,000-lb. load over light rails. This may be so over carefully laid, clean track, with ties close-spaced, and with car wheels well lubricated; but over the ordinary rough contractor's track, 20 lbs. is much too low an estimate.

In the "Coal and Metal Miners' Pocket Book" is a table giving actual results of traction tests, including several hundred separate tests under varying conditions. From these tables we have summarized the following:

| | Per short ton. |
|---|---|
| Pull to start mine cars (old style) loaded............ | 90 lbs. |
| Pull to start mine cars (new style), empty............ | 80 " |
| Pull to keep up ¼-mile per hour speed (old style car). | 50 " |
| " " " " " " " (new style car) | 33 " |
| " " " " 4½-mile " " (old style empty) | 56 " |
| " " " " " " " (old style full) | 66 " |
| " " " " " " " (new style empty) | 30 " |
| " " " " " " " (new style full) | 38 " |

The foregoing was for trains of 1 to 4 cars, but with a train of 20 cars the pull was 46 lbs. for old-style cars and 26 lbs. for new-style cars per short ton on a level track. The mine cars used had a wheel base of 3½ ft.; they weighed 2,140 to 2,415 lbs. empty and 7,885 to 9,000 lbs. loaded. The diameter of the wheels was 16 ins., and of axles 2⅛ ins. for old-style car to 2½ ins. for new-style car, with a steel journal 5¼ ins. long, well lubricated in all cases, in fixed cast-iron boxes. The new-style cars had better lubrication, the importance of which is well shown by the results of the tests. The track in the mine was level and in good condition. We know of no tests on car resistance of small cars that are as extensive and trustworthy as the foregoing.

The resistance to traction on upgrades is practically 20 lbs. per short ton for each 1% (1 ft. rise in a 100 ft.) of upgrade; so that on a 5% grade, for example, it will require a 100-lb. pull on a rope to overcome the gravity resistance of a ton, plus 40 lbs. more to overcome the rolling resistance, or a total of 140 lbs. per ton. Working steadily for 10 hours, a single horse can just about do the work necessary to pull a car up a 4% grade, that is the tractive force of a 1,200-lb. horse is about 120 lbs. working steadily all day long; in other words, a horse can exert a pull on a rope of about $^1/_{10}$ its own weight. Many a contractor will say that this is absurdly low, but experience has shown it to be not far from right. However, for a short time a horse, like a man, can exert a great deal more force.

The author has had a heavy team pull a load of 10,000 lbs. up a 5% grade on a macadam road; and actual test on a spring balance has shown that a light pair of mules have exerted a pull of 1,000 lbs. (or 500 lbs. each) ascending a steep earth road.

So it is evident that for a few minutes a horse can exert a pull about 500 lbs. if he has a good foothold, but he must have long rests between such

exertions. It requires about two times as much force to start a car as it does to keep it in motion, hence a horse should never be worked within half his capacity, that is he should not be required to exert over 250 lbs. pull at any place where cars are apt to stop.

A dump car with a box 2 ft. deep, 5 × 5½ ft., holds 2 cu. yds. water measure, but even when heaped up with loose earth it will seldom hold 2 cu. yds. of earth measured in cut. Such a dump car weighs about 2,000 lbs. and 2 cu. yds. of earth (place measure) weigh about 5,400 lbs., or a total of 7,400 lbs., or 3.7 tons. A strong horse could pull one such car loaded on a level track all day long, and could go up a short 4% grade occasionally if he did not stop on the grade. Cars will coast down a 2% grade once they are started, so it is not advisable to have steeper grades, when brakes are not provided for the dump cars.

On the Chicago Drainage Canal a great deal of material was loaded with a steam shovel into small dump cars that were hauled away by horses on a slightly down grade to the foot of an "incline," where they were pulled with a ¾-in. wire cable to the top of the bank by a 60-HP. winding engine (13 × 16 ins. cylinder) stationed at the top of the bank; the cars were then hauled to the dump by horses. One team pulled two cars holding 3 cu. yds. each, or five cars holding 1 cu. yd. each. The same team could pull back 6 empty 3-cu. yd. cars. Two faces were worked in opposite directions from each "incline." Even then the "incline" engine could handle more material than two shovels could excavate. In one case 2,400 cu. yds. were raised in 10 hours. An extra team was used to "spot" the cars.

In excavating mud the author once used an incline 120 ft. long rising 12 ft. in that distance; then there were 80 ft. of level track at the foot of the incline and 40 ft. of level track on a trestle at the top. Using a team of horses and a single car hold-

ing 1 cu. yd. with a hemp rope passing around a pulley at the top of the incline, 120 carloads were raised per 10 hours. The team actually traveled 14½ miles a day in doing this work, part of which it will be seen was exceedingly hard.

There are many comparatively small jobs where a few dump cars and some light rails will enable a contractor to move earth far cheaper than with wagons. Ordinarily the dumping of the cars where the fill is light will cause the earth to run back and block the track. It is therefore customary first to build a temporary trestle, and fill it in with earth; then the track is shifted from time to time to keep it close to the edge of the embankment. Even where the fill is so light as not to pay to trestle, the author has found cars economic; for then the earth can be shoveled from the cars at a cost of 6 cts. per cu. yd. (wages being 15 cts. per hour), which is often less than the added cost of hauling with wagons.

In Engineering News, June 12, 1902, Mr. Joseph Wright describes and illustrates "A Method of Bank Construction by Dumping from Movable Trestles." The bank was to be about 1½ miles long and 6 ft. high for a railroad, over practically level ground. A trestle was built in sections 17 ft. long; the side on which the earth was dumped being closely sheeted with plank. Each section of the trestle rested on two long wooden skids, so that one team could shift each section of the trestle when it became necessary to move. Let it be noted, however, that if the embankment had been much over 6½ ft. high the pressure of the earth against the plank sheeting would have shifted the trestle without the aid of a team; and means would have had to be provided to keep the trestle in place. This is an ingenious method, and enables a very long embankment to be built without leaving any timber in the bank.

A method well adapted to similar conditions, but where the bank is high, is described and illustrated

in Engineering News, Jan. 16, 1902. A fill ¼ mile long and 60 to 65 ft. high was to be made over practically level ground. Instead of trestling, the contractor had a light movable steel bridge made with a span of 150 ft., and 14 ft. between the trusses, the weight being about 40 tons.

One end of the bridge was supported by the bank, on rollers; the other end was supported by a wooden tower or trestle 60 ft. high, made with bents, each having three "stories." The tower was 16 ft. wide on top and 25 ft. wide at the bottom, and it rested on wheels running upon rails 25 ft. apart. Guy ropes prevented overturning from wind pressure.

By using block and tackle, one team of horses can shift the trestle with the bridge a distance of 30 ft. in three hours' time. A train of 12 dump cars (3 cu. yds. each) running on a 36-in. gage track is hauled by a locomotive.

Three cars are dumped at a time, then the train is shifted, and three more cars dumped exactly where the first three stood. This dumping in one place is supposed to pack the earth and prevent future settlements. Thus far settlements have not occurred. The material is clay, and the steam shovel, working night and day, is loading about 1,600 cu. yds. every 24 hours. Had a temporary trestle been built the cost for timber would have been double the cost of the movable steel bridge and tower, it is said. These two methods of saving timber in trestling for fills (where timber is scarce) illustrate the possibilities of great saving in cost when the contractor has a full knowledge of his business—and a goodly share of ingenuity. The author would suggest that the first movable trestle method might be used even for very high fills, simply by building the fill up in layers of say 8 ft. thick the full length of the fill; and by so doing a more compact embankment would be secured. In building an embankment 16 ft. high across Otisco Lake, N. Y., the author used round unsawed tim-

ber with two posts in each bent; the caps were sawed and the beams between bents upon which the rails rested were also sawed timber that was saved and used again and again. In this way the cost of trestling was made very slight.

With carpenter wages at 25 cts. per hour, and labor at 15 cts. per hour, the cost of framing and erecting trestle was $6 per 1,000 ft. B. M., or about ½ ct. per lineal ft. of heavy timber.

Wherever it is desired to use a movable trestle as in the case just described, or a movable platform trestle for loading cars with wheel scrapers as described in Chapter VIII., the author would recommend the use of cedar both for floors and bent timbers, on account of its less weight for equal strength in beams or posts. Cedar, contrary to general opinion, makes a durable flooring for bridges; for while easily indented and cut by horses' calks, this very splintering acts to preserve the body of the plank by forming a thin mat of wood and dirt.

In Engineering News, Feb. 26, 1903, Mr. L. L. Wheeler describes an ingenious way of overcoming a difficulty at Sterling, Ill. An embankment had to be built across a marsh where water was 3½ ft. deep. He waited until the ice formed thick enough to support a track and dump cars, then laid the track across the ice and dumped the earth to one side; as the ice settled under the earth load the track was raised and earth tramped under it.

In excavating narrow open cuts, or tunnels either in earth or rock, a small dump car running on 16-lb. rails is often used with profit. A man can readily push a small dump car holding ⅓ cu. yd. of earth (nearly half a ton) on a well laid, clean level track at a walk of 220 ft. a minute all day long. With wages at 15 cts. per hour the cost of moving earth in this way is $^7/_{10}$ ct. per cu. yd. for every 100 ft. of haul, which it will be seen is very much less than the cost, 5 cts. per cu. yd., by wheelbarrows for every 100 ft. of haul. In view of this low cost, and

in view of the ease with which a 16-lb. rail track can be laid and shifted when made in one rail sections, it is surprising the contractors do not oftener use the small end dump car pushed by a man. For handling the materials in making concrete, and for moving the concrete to place, this method can often be used with decided advantage; and other uses will occur to any contractor who is wide-awake.

Coming now to a consideration of all the items that go to make up the cost of hauling earth in dump cars, we shall first take up hauling with a contractor's locomotive.

Trautwine (p. 749) assumes that a contractor's locomotive will readily haul a train of 10 dump cars holding 1½ cu. yds. each at a speed of 5 miles per hour. He assumes 9 minutes lost time each trip loading and dumping; and a train force as follows:

| | |
|---|---|
| 1 Engineman | $3.00 |
| 1 Dump Foreman | 3.00 |
| 3 Dumpmen @ $1.50 | 4.50 |
| ½ ton coal @ $3.00 | 1.50 |
| Oil, water, etc. | 1.00 |
| 1 Switchman | 1.50 |
| | $14.50 |

On these assumptions he figures that a locomotive in 10 hrs. will haul as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| 4,350 | cu. | yds. | with | a | 1-mile | haul. |
| 2,700 | " | " | " | " | 2 " | " |
| 1,950 | " | " | " | " | 3 " | " |
| 1,500 | " | " | " | " | 4 " | " |
| 600 | " | " | " | " | 10 " | " |

Trautwine then makes a very serious error, for he entirely overlooks the fact that no steam shovel can load the full 4,350 cu. yds. in a day that the locomotive might handle on a 1-mile haul; and he fails to see that in reality the cost of hauling with

a contractor's locomotive does not depend upon the length of haul at all. In reality it matters very little whether the haul is long or short; for the output of the steam shovel is the limiting factor, and a shovel may not average 600 cu. yds. per day. A small locomotive will cost about \$3,000, and 40 dump cars (2-cu. yd.) will cost about \$2,000. Each tie (6 × 6 ins. × 5 ft.) contains 15 ft. B. M., which, at \$15 per M. ft. B. M., means 22½ cts. per tie. Therefore, with ties about 3 ft. center to center, the cost of ties per mile of track is not far from \$400. Using 25-lb. rails at \$30 a ton the cost is \$25 per 100 ft. of track, or \$1,320 a mile for rails. Including side tracks, bolts, fish plates, etc., a mile of light track will cost about \$2,000, and after delivery of materials can be laid for \$100 if no grading is required. The ties will last 4 to 6 jobs before they are so cut up from pulling and driving spikes as to be valueless. Hence, we may say roughly, that a plant consisting of one locomotive, 40 cars, and a mile of track costs \$7,000; and it will cost \$100 to lay a mile of track, \$100 per mile for wear on ties, and about \$50 per mile for labor pulling track to pieces when the job is done, a total of \$250 per mile of track. The interest and depreciation of the plant will be about \$1,000 a season, or \$10 a day if 100 working days a year can be counted upon. It must be remembered, too, that unless the track can have at least 2% down grade, a second locomotive will be needed to "spot" the cars for a steam shovel.

According to the Chicago Canal experience (see Chapter X.), two skilled mechanics or blacksmiths and about 5 laborers were required to keep the cars and track, shovel and two locomotives in repairs, or about \$12.50 a day.

We think it safe to ordinarily count upon \$10 a day as above given for the interest and repair item of a small locomotive, 40 cars, and a mile of track, which, added to the force account of \$22, makes a total of \$32 a day. If the average output of the

shovel is taken at 500 cu. yd. a day (10 hrs.) we have $\frac{\$32.00}{500} = 6.4$ cts. per cu. yd. for hauling and dumping with locomotive and cars, to which must be added \$250 for track laying, etc., divided by the total number of cu. yds. that can be moved before the track is torn up, and by "torn up" we do not mean merely shifting it on the dump or in the pit. If 10,000 cu. yds. are to be moved over the mile of main track, then the track item alone will be $\frac{\$250.00}{10,000} = 2\frac{1}{2}$ cts. per cu. yd., which, it will be seen, is a very important item; but if 100,000 cu. yds. are to be moved, the cost is only $\frac{1}{4}$ ct. per cu. yd. for track laying, etc. If a second locomotive is used to spot the cars, we have about \$5 a day for wages, coal, and oil and say \$3 a day for interest and depreciation, a total of \$8, which, divided by 500 (the number of cu. yds. loaded) is 1.6 cts. per cu. yd. for "spotting" the cars. Thus the total cost of hauling a mile, more or less (it really makes little difference, as we have seen, what the haul is), is $6.4 + 1.6 = 8$ cts. per cu. yd. $+ 2\frac{1}{2}$ cts. if the yardage is 10,000, or $\frac{1}{4}$ ct. if 100,000. If the haul were 800 ft., for example, the cost by locomotives would be 1 ct. per cu. yd. per 100 ft., or more than with small wagons; if the haul is 1,600 ft. the cost would be $\frac{1}{2}$ ct. per cu. yd. per 100 ft. which is still higher than with 3-horse wagons. But it should be remembered that wagons do not work as well as cars with a steam shovel, due to the lost time in moving the full wagon away from and the empty wagon up to the shovel.

In widening cuts on railway work it is often necessary to use flat cars holding 5 to 10 cu. yds. of earth, seldom over 7 cu. yds., unless drop sideboards are provided. A flat car is ordinarily $8\frac{1}{2}$ ft. wide over side sills and 32 ft. long over end sills. In freezing weather the floors of the cars should

be sprinkled with brine just before loading, a man with an ordinary garden sprinkler being detailed for the work. The brine will prevent the earth from freezing to the car floor for 3 or 4 hrs.; but a loaded car should never be left standing over night, for it will take 4 to 6 men a day to unload a frozen car load of earth.

Flat cars are ordinarily unloaded with an unloading plow, the Barnhart plow being a good type. The car carrying the plow is attached to the rear of the "mud train" of 10 to 30 cars. One end of a 1¼-in. wire cable is hooked to the plow and the other end, which is attached to an ordinary car coupling link, is coupled to a car or to the engine. Usually this cable is 400 ft. long and extends over 12 cars. The brakes on all these 12 cars are set tight, and the engine is started with the forward cars if there are more than 12 in the train. If the rear 12 cars are pulled along, blocks are laid on the track to hold them, or a few cars may be chained to the track. The engine moves ahead at a rate of 2 or 3 miles an hour, until the plow has traveled the length of the 12 cars, and the material is thus scraped off the side of the cars. The engine is backed up a few feet, when 4 to 6 men throw the cable off to one side. Then the remaining full cars are backed up to the last half empty car where the plow is, the cable is coupled to the engine and the plow pulled forward as before. The plow is left on the last car which is unloaded by the next train. The time of unloading is 10 to 30 mins., average 20 mins., the engine doing as much in that time as 8 or 10 men would do in a day.

When unloading on curves the time is longer, for snatch blocks must be used to keep the cable on the cars. A snatch block every third car is generally enough. The cable passes over the snatch block sheave, and the block is held with a chain passing over the side of the car, and fastened to the bolster or arch bar of the car. When the plow reaches a snatch block it must be stopped, the

block and chain being removed and carried forward. Unloading this way takes about twice as long as on straight track.

When much material is to be handled on flat cars, two things should be done; (1) the cars should all be rigged with hinged side boards that can be dropped down when unloading, for then a car will carry 14 cu. yds.; (2) and a hoisting engine should be rigged up on a car by itself for the purpose of pulling the plow cable instead of using the locomotive for that purpose. A 10 x 12-in. double cylinder engine with a 1-in. cable for loose gravel, 1⅛-in. for heavier material, will unload a train of cars often in half the time taken by locomotives, since the cars need not be blocked or chained to the track, and there is little danger of breaking the cable as often happens where a locomotive pulls the plow. Furthermore, since this unloading engine on its car is a part of the "mud train," it can do the unloading while the whole train is moving ahead, and thus spread the material along a greater length of track.

After the material is unloaded by a plow alongside a track it can be most economically spread with a leveler or spreader, of the Harris & Carter, or Edson type. This spreader is a car provided with projecting side wings which can be raised by a winch when not in use. The Edson scraper will spread the material to a distance of 15 ft. from the rail, and can be adjusted to cut 6 ins. below the bottom of the ties, thus forming the subgrade of the widened roadbed.

The spreader car is loaded with 5 to 15 tons of scrap to hold it to its work, and moves at 6 to 10 miles per hour, thus leveling off a ridge a mile long in 6 to 10 mins. Ordinarily the spreading is done by the last train before the close of the day, but in freezing weather spreading must be done oftener.

We shall now pass to hauling cars with horses, which, as we shall see, is ordinarily cheaper than

with locomotives for short distances, unless the contractor already has the locomotives on hand.

Referring to the forepart of this chapter, it is seen that a strong team will pull about 5 cu. yds. of earth over fairly level track at a walk. With team and driver at 35 cts. an hour, and speed of team 2½ miles an hour, or 220 ft. a minute, the cost is $^1/_{330}$ of an hour's wages, or a trifle more than $^1/_{10}$ ct. per cu. yd. for every 100 ft. of haul from pit to dump. At this rate it is as cheap to haul with horses as with locomotive up to a distance of nearly a mile, provided, of course, that a contractor has to rent or buy the locomotive, and does not already have it on hand. A locomotive, however, possesses one decided advantage in that it can push cars out into a trestle; whereas, a block and tackle must be used with a team to get the cars out onto the trestle. If there were no delays either at the pit or at the dump, and a team were moving all the time, we thus see that it could haul 3,300 cu. yds. 100 ft., or 100 cu. yds., 3,300 ft. Manifestly the first rate is impossible not only because there are necessary delays, but because enough men could not be got around the cars to load 3,300 cu. yds. a day. Ordinarily where cars and a team of horses are used about 20 shovelers are employed, seldom more than 30 shovelers, not infrequently only 10. Ten shovelers working at a fair face may each average 15 cu. yds. a day, which a team could haul in cars a distance of 2,200 ft., making 30 round trips if there were no delays. As a matter of fact there will be about two minutes consumed each trip changing team from the empty to the full cars, and another four minutes at the pit dumping. Delays while shifting track will ordinarily add about four minutes more each trip, making a total of 10 minutes "lost time" each trip, or two minutes for each cu. yd. This means a cost of $^1/_{30}$ hour's wages of team and driver (nearly 1 ct.) for lost time per cu. yd. hauled. But in this 10 minutes "lost time" the team could travel 1,100 ft. and re-

turn; hence, instead of travelling 2,200 ft. and return as above assumed, the team would really have time to travel only half that far. This leads us to see that where 10 men are shovelling, we should not count upon a haul of less than about 1,100 in estimating the cost according to the rule that follows:

Rule IX.—To find the cost per cu. yd. of loading and moving average earth with cars and horses (working at a "face") add together these items:

1 hour's wages of laborer undermining and shoving earth;

$^1/_{80}$ hour's wages of team with driver "lost time,"

$\frac{1}{3}$ hour's wages of man on dump, dumping, making trestle, and track shifting;

then add $^1/_{330}$ hour's wages of team with driver for each 100 ft. of haul, assuming never less than 1,000 ft. haul. With wages of men at 15 cts., and team with driver at 35 cts. per hour, this rule becomes: To a fixed cost of 16 cts. add $^1/_{10}$ ct. per cu. yd. for every 100 ft. of haul, making the cost of hauling never less than 1 ct.; and add the cost of materials for the dumping trestle plus $250 per mile of track, divided by the total number of cu. yds. moved over the track before it is torn up.

Note: Where a steam shovel is used, hauling cars by horses is especially disadvantageous because of delays in switching and "spotting" cars in such short trains as team hauls.

# CHAPTER XII.

## How to Handle a Steam Shovel Plant.

Having given the elements of cost of excavating with steam shovels, it is well to consider separately the various methods of handling a steam shovel plant.

Mr. E. A. Hermann's excellent monograph on this subject is now out of print, but we are in-

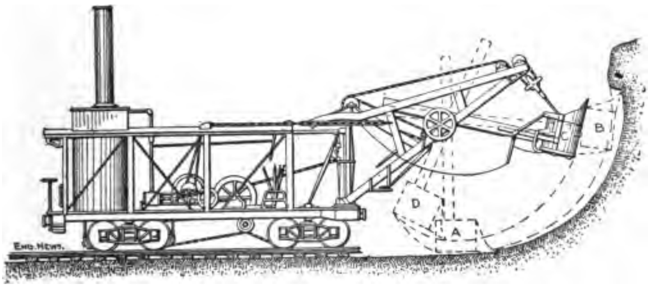



Fig. 1.

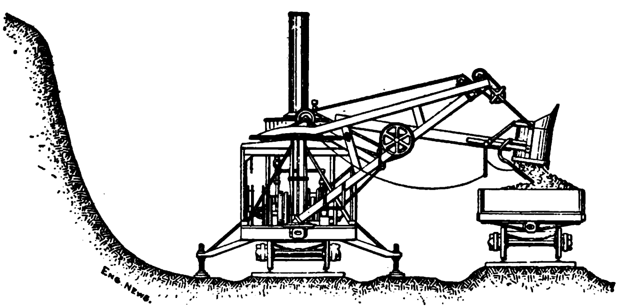



Fig. 2.

debted to his work for many of the cuts used in this chapter.

There are four types of steam shovel, three being of the bucket or scoop type and one of the clam shell or orange peel type.

Fig 3. Thew Shovel With Crew of Two Men.

The bucket shovel which is the type ordinarily used may be classified thus: (1) Heavy machines mounted upon trucks of standard gage and designed for use on railway work only; (2) Machines of heavy or medium weight mounted on trucks of other than standard gage; (3) Light traction machines mounted on traction wheels and designed to propel themselves over ordinary roads, and across land not too soft, without rails to run upon.

Each type of machine has its place of greatest uesfulness, but the light traction shovel seems destined to find an ever-increasing field.

Figs. 1 and 2 show the general features of the types of machines designed to run on tracks. It will be noted in Fig. 2 that jacks are used at the sides to brace the machine. A shovel has recently been placed on the market that can dispense with these jacks; it is made by the Thew Automatic Shovel Co. of Lorain, Ohio, and is shown in Fig. 3. It will be seen that this shovel is modeled somewhat upon the lines of the locomotive crane or McMyler derrick, the whole upper part of the machine revolving on a turntable. The Thew shovel can, therefore, describe a complete circle, dumping its load in the rear if need be. We need not here describe or illustrate the various shovels made, since catalogues can readily be had of any or all of the following manufacturers:

The Marion Steam Shovel Co., Marion, Ohio; The Bucyrus Co., South Milwaukee, Wis.; The Toledo Foundry and Machine Co. (Mfrs. of the "Victor"), Toledo, Ohio; The Vulcan Iron Works Co., Toledo, Ohio; Osgood Dredge Co., Albany, N. Y.

An orange-peel excavator consisting of a 1-cu. yd. bucket suspended from the boom of a derrick was used to advantage on the Massena Canal, N. Y. (see Eng. News, Dec. 15, 1898). The derrick worked from the top of a 35-ft. face of cheeselike clay, dropping the bucket over the face of the cut into the broken down material at the bottom of the

face, raising the load and dumping into cars alongside. This machine handled 600 cu. yds. per 10-hr. day at a cost of $20 for labor. While this is a method of limited applicability it is nevertheless worthy of being remembered.

## Operation of Steam Shovels.

All movements of the dipper are controlled by two men, the cranesman and the engineman. The engineman operates the levers that cause the raising or lowering of the dipper and the swinging it right or left. The cranesman regulates the depth of cut made by the dipper, releases it from the bank when full, and trips the latch of the bottom door when ready to dump the bucket. These two men must learn to work in perfect unison, for the output of the shovel depends very largely upon their combined skill. After dumping, the bottom door latches by its own weight when the bucket is swung down and back ready for the next scoop. In loose gravel a bucketful can be loaded every ½ to ¾ min., in hard materials 1½ to 2 mins., but one would make a grievous blunder were he to figure the daily capacity of a shovel on any such basis, for there are always delays in moving the shovel forward and placing the jacks which has to be done about every 4 or 5 ft., delays in "spotting" cars ready for loading, etc. The laying of a new section of track, moving the shovel forward 4 ft. by its own power, and jacking up will ordinarily consume 3 or 4 mins.

The width of the cut or swath excavated by a shovel varies from 18 ft. for the smaller shovels to 40 ft. for the larger ones. The depth of a cut depends largely upon the material; easy running sand or gravel might be worked almost to any depth; side hill cuts in loose gravel up to 300 ft. in height have been taken. There is danger in such cases of a slip that will bury the shovel. Cuts 60 ft. deep are common in gravel pits. In average material cuts of 25 to 30 ft. are common, while in

hard tenacious material the cut should not be deeper than the height to which the dipper can be raised—that is, 14 to 20 ft. Where cuts are very shallow the ordinary steam shovel can not work economically at all, although the Thew shovel above mentioned seems better adapted to shallow cuts than any of the others. The reason for the increased cost in shallow cuts is quite apparent if one stops to "figure," but in deepening the Erie Canal, for example, where the cut was only 1 to 2 ft. deep, we have seen steam shovels used by contractors who evidently had not stopped to "figure" before hand—they did their "figuring" afterward, to their sorrow.

If a shovel could excavate a block 18 ft. wide by 2 ft. deep by 4 ft. forward, each move, it would excavate less than 3 cu. yds. before a move would be necessary. Obviously the bucket would go out about half full each scoop, but even assuming that it were full, and held 1 cu. yd., we see that more than half the shovel time would be spent in moving forward. If the shovel load were ½ cu. yd., which is higher than the average in such a shallow cut, the shovel would be doing useful work about 2½ hours out of the 10!

In Chapter X. we have given several actual crews, so we need only say that beside the cranesman and the engineman there are usually a fireman, a blacksmith, a blacksmith's helper, two to five car repairers, and four to ten laborers. In average soil four laborers are enough, but in tough material that must be broken down by wedging or blasting ten and sometimes more are needed, for which see Chapter X.

For breaking down the bank in front of the shovel the men are provided with a 16 ft. hickory or ash pole, shod with a pointed spike.

The blacksmith and helpers are provided with a portable shop, forge, etc.; their principal work consisting in repairing side boards, chains, etc., on the cars.

WIDENING RAILWAY CUTS.—This is a class of work for which steam shovels are so often used that we shall consider the methods of attack in some detail.

Before the shovel can begin work it is generally necessary to excavate a section of the cut, A B, Fig. 4, 30 to 50 ft. long, using wheelbarrows, drag-scrapers or the like. The switch A B is laid off the main track for the shovel to travel upon, and the "mud train," of 10 to 20 flat cars, is drawn up on the main track ready to be loaded. The shovel is moved forward as soon as all the material within reach has been loaded, and to do this short sections of track 4 to 6 ft. long are provided. These

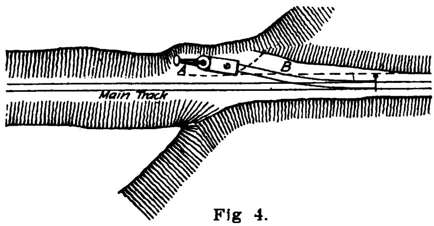


Fig 4.

sections are moved by attaching them to the dipper with a chain, and dragging them from the rear to the front. When the shovel has moved forward the length of a full rail, 30 ft., rails are laid to extend the switch so as to keep it close to the shovel. This is particularly desirable where the bank is apt to cave, for then the shovel can be moved back if caving is anticipated.

Since railway hauls are usually long it seldom pays to have less than two locomotives with trains, and unless automatic dump cars are used two trains will be found economic even on short hauls of ½ mile or so. This, however, is a matter that the contractor or engineer may quickly determine by a little observation in each particular case. Three engines and crews will be needed for hauls

of more than 10 miles, or where the traffic on the main line is so great as to cause many delays in moving the "mud train." A contractor in estimating the cost of widening railway cuts must be careful to allow liberally for delays due to traffic on the main line, which may be 40 to 70% of the working 10-hr. day.

As shown in Fig. 2, the track on which the shovel runs should be a foot or two lower than the main track, not only to provide for material that drops off the cars and that washes in from the sides of the cut, but also to drain the ballast on the main track.

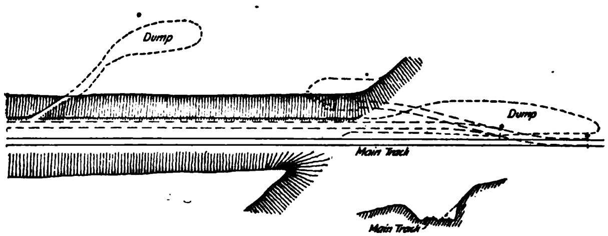



Fig. 6.

Where the traffic delays do not exceed 5 hours out of the 10 working hours it is generally considered more economic to work as just described, but when the delays become more frequent, another method must be employed.

A narrow cut is first made by hand shoveling so that a switch track for the "mud train" may be laid, Figs. 5 and 6. In doing this hand excavation, flat cars are often loaded by men with wheelbarrows, but this method is slow since only a very small gang of men, 6 to 10, can be worked at the face of the cut. Three to six flat cars are run out on the side switch, and a plank runway laid on the end car nearest the face of the work. The men load the car farthest from the face first. The writer would suggest that a "locomotive crane" or traveling derrick moving back and

forth on the main track could be used to excellent advantage instead of wheelbarrows for work of this character; and in soft material if provided with a clam-shell bucket such a traveling derrick could be operated with very little hand shoveling at all. Upon the approach of a train, the traveling derrick can rapidly move to the side switch back of the mud train. Instead of flat cars, contractor's dump cars may be used and draw away by horses to the dump, or one horse dump carts many be used. The work is too confined for scrapers to be used.

After the narrow cut has been made, the side track is laid and the steam shovel run in on a second switch shown in Fig. 5.

CUTTING DOWN GRADES.—It often becomes necessary to cut down grades at summits, when methods of attack differing from the foregoing must be adopted. Figs. 7 and 8 show the most common method of attack where the mud train is on the main track. It will be noted in Fig. 7 that the steam shovel track is on blocking, the grade of its track being about 2 ft. below that of the main track which is about as low as the ordinary shovel can work and dump into the cars. The blocking is made of 6 × 12-in. × 4 ft. sticks upon which 12 × 12-in. track stringers are laid, and the track is kept level. This blocking is generally 5 ft. high, for the ordinary shovel can dig only 5 ft. below the track it runs upon; thus it will be seen that the depth of each slice or cut is only $5 + 2 = 7$ ft. and as shown in Fig. 7 the successive cuts are parallel with the old main track grade until the last cut is made to final grade. This shallow cutting and the blocking up of the shovel track both make the work somewhat more expensive than ordinary. The engineer in fixing a new grade should have in mind the fact that it is cheaper to make an even number of full cuts of say 7 ft. each than to plan so that a fractional part of a full cut must be made.

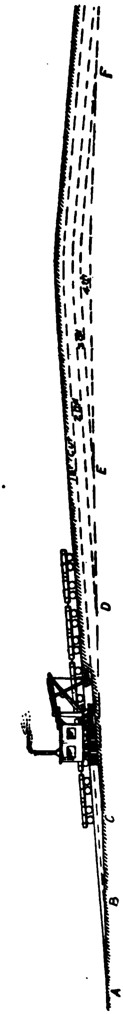



Fig. 7.

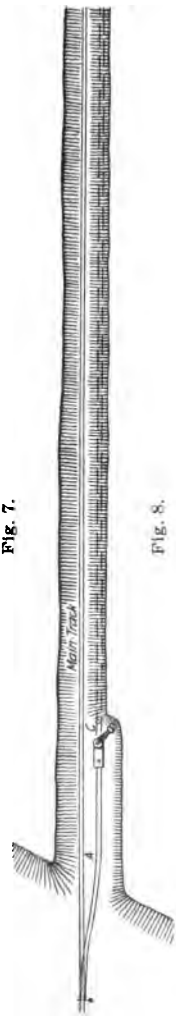



Fig. 8.

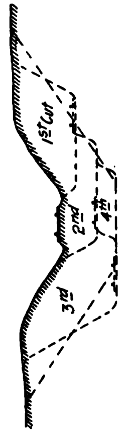



Fig. 10.

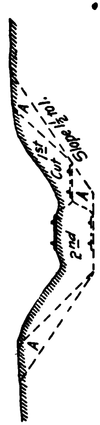



Fig. 9.

Some shovels cut 8 ft. below their track instead of 5 ft., and for extensive work of this kind are evidently far more economic. Figs. 9, 10 and 11 show various cross-sections of cuts.

It should be noted that a steam shovel cuts a 1 to 1 slope, whereas the finished side slopes must

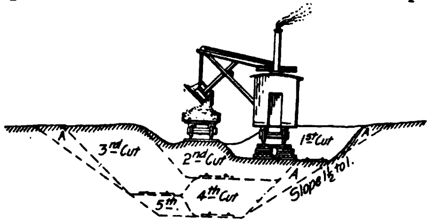



Fig. 11.

often be $1\frac{1}{2}$ to 1. In that case the shovel can either undercut, as in Fig. 10, or it can supercut, as in Fig. 11. Undercutting is the most economic for no more material is moved than is necessary; and

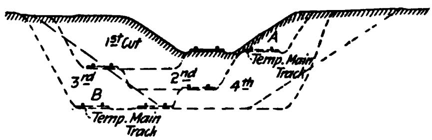



Fig. 12.

the rains will slough off the upper part of the cut until the desired permanent side slope is obtained. But if the work is super-cut, the slopes must be trimmed by hand, which is an expensive method.

Where traffic is very heavy a temporary side track must first be built, as described under Wid-

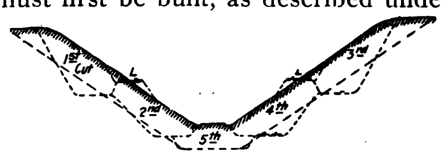



Fig. 13.

ening Cuts. Fig. 12 shows such a temporary track at A. If the depth of the original cut exceeds the height to which the dipper can be raised, and if the material is so tenacious that it cannot be broken

down by the men with bars, then the cuts are made as in Fig. 13, where L L are the temporary loading tracks.

On double track railways the traffic may be diverted to one of the tracks while the other is used for the "mud train."

It will be seen that each cut must be studied as a separate problem, the object being to secure the necessary deepening with the fewest possible number of "swaths" or cuts.

RAILWAY CONSTRUCTION WORK.—Where an entirely new cut is to be taken out, the work may be attacked in a way somewhat different from the widening or deepening of existing cuts. There are two methods of attacking a new cut: (1) The through-cut method; or (2) The side-

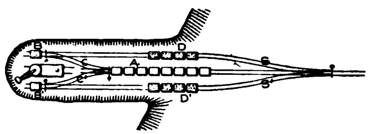


Fig. 14.

cut method. The work that we have just been describing comes under the side-cut method; that is, the cars are loaded upon a track laid alongside of the shovel and in advance of it. The through-cut method is shown in Fig. 14, from which it will be seen that the loading tracks are carried through at the same time with the shovel track. One of the loading tracks $S^1$, is often dispensed with, although the work is greatly facilitated by having two cars, B and $B^1$, always on hand to be loaded. In through-cut work only contractors' dump cars can be used, since it is obvious that a flat car could not be run up far enough to be loaded. Moreover, the frequent moving of the cross-over tracks, C and $C^1$, makes it important that the track be a light one. The great objection to the side-cut method is that the grade of the natural ground is generally so steep that a side track cannot be

laid over which a locomotive can travel, and to get a side-track through the shovel often has to do a lot of dead work, as shown in Fig. 15, where the shovel is shown in the act of cutting down the top of the hill so as to make a trackway for the loading track.

Wheel scrapers or the like can in many cases be used in such a case, and the material may be wasted off to one side or put in the fill, if the haul is short. Where a track can be laid at once on the natural ground, or where such cutting as is shown in Fig. 15 is small, the side-cut method is of course to be preferred since the cars are more quickly

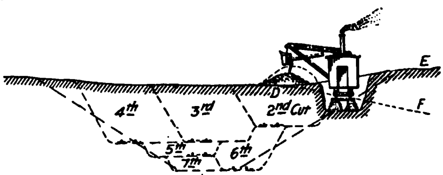



Fig. 15.

"spotted," that is, placed alongside the shovel ready to be loaded.

Where the through-cut method is used, as in Fig. 14, either a team of horses is used to spot the cars, or a light 4-HP. hoisting engine with cable may be used, the engine being generally stationed on the bluff in front of the shovel. Some contractors use an extra contractor's locomotive for spotting the cars, and upon the whole that is the best method.

If the steam shovel used is of the traction type, weighing about 35 tons, it can readily climb the summit of most hills that are to be cut down, and attack the work there by the side-cut method, provided the cars can be moved over their track. A small locomotive will climb a 10% grade with 4 empty cars, so that if the grades are greater, the only methods remaining are to load into wagons, or to use a hoisting engine to pull the empty cars up and let the full ones down to the dump.

By providing snubbing posts against which the

wire cable rubs, such a cable may be used for long distances (1,000 ft.) even on curves; and by using a second hoisting engine to take the cars when the first reaches the "end of its string," distances up to nearly half a mile may be covered. Where cables are used in this way on the side-cut method, a train of 4 to 6 cars is usually operated, and the track must be laid on a grade of at least $1\frac{1}{2}$ to 2% to insure that the cars will start and run down by gravity. Each train of cars is pulled up past the shovel, and the last car loaded first; then the hoisting engineman slacks on his brake and lets the cars "down a notch," so that the next one can be loaded.

There is always some lost time in dropping the loaded cars out of the way and getting up a train of empties, even where a double-drum engine is used, but the shovel can be moved forward during this interval and so reduce the lost time. The cable method is not as economic as the use of contractor's locomotives, and is not to be used where it can be avoided.

CANAL EXCAVATION.—We come now to a class of work differing considerably from railway excavation. In modern canal work the material taken from cuts is not used to make fills, but is wasted. This generally makes an entirely different method of attack necessary, for while the upper part of the excavation can be taken out by the side-cut method, as the excavation increases in depth a time is reached when locomotives can not climb the grades necessary to get out of the canal prism to the waste dumps. Since the shovels do not have to make frequent moves from hill to hill as in railway work, a larger type of shovel can be used; but there is no gain in using larger shovels unless large cars can be delivered rapidly enough to keep the shovel busy, or unless the material when blasted breaks up in such large chunks that a small shovel can not handle it at all.

Figs. 16 and 17 show arrangement of track on

two sections of the Chicago Drainage Canal work. Cars were handled with contractor's locomotives. Both these examples illustrate the use of the side-cut method of excavating the upper part of a canal section.

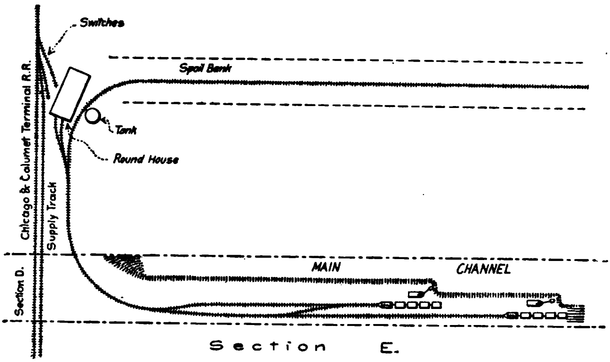



Fig. 16.

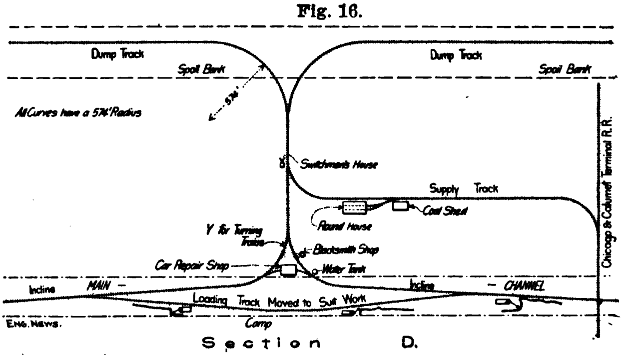



Fig. 17.

When the depth of the cut reaches a point where the locomotives cannot move the trains up the incline, it becomes necessary to install a hoisting engine plant, using a cable to pull cars up the incline.

The cars may be loaded by the side-cut method as before, and run to the foot of the incline either

by locomotives or by teams of horses, and there hoisted by the engine. At the top of the incline, either horses or a locomotive may be used to haul to the dump.

Since the hoisting engine must be moved when the haul to the shovel becomes very long, the hoisting engine may be mounted on a platform car 18 × 40 ft., running on a very wide gage track. A 13 × 16-in. double-drum engine has handled 2,500 cu. yds. per 10-hr. day on one of these inclines. As such a plant costs only $3,000, and is very flexible, being easily adapted to any particular kind of work, it is evidently meritorious. Where an incline serves only one shovel, instead of two, a much smaller engine will evidently serve.

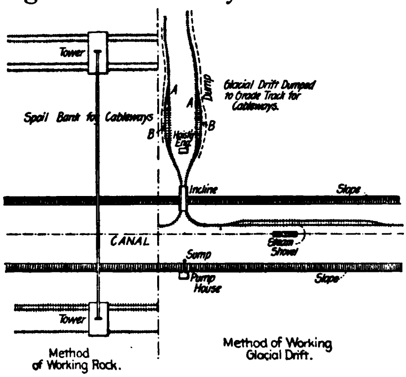
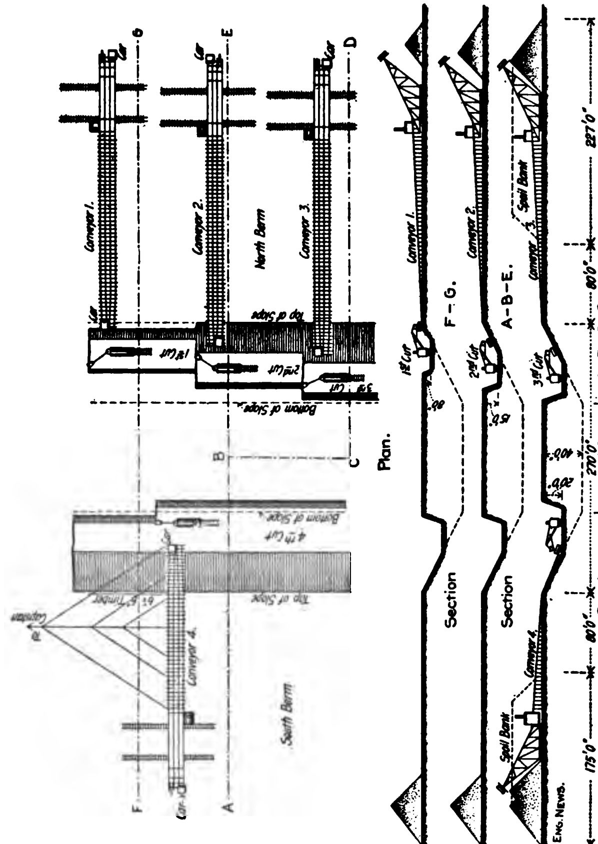



Fig. 18.

Fig. 18 shows the arrangement of tracks for use with such an incline. It will be noted that the tracks on the dump are so arranged that the loaded cars can be run on track A, so as to pass the empty cars returning on track B.

By using locomotives instead of horses to handle the cars it would not be necessary to move the incline often, unless it were to keep down the investment in rails and ties. Having briefly discussed the shovel and fixed incline method, we may take up the shovel and traveling incline method. There



Plan.
Conveyor 1.
Conveyor 2.
Conveyor 3.
Conveyor 4.
North Berm
South Berm
Car
1st Cut
2nd Cut
3rd Cut
4th Cut
Top of Slope
Bottom of Slope
Section
F-G.
A-B-E.
A-B-C-D.
Spoil Bank
Eng. News.
227'0"
80'0"
270'0"
110'0"
175'0"


Fig. 19.

are several kinds of traveling inclines, but in all cases each incline is provided with two cars operated by wire cables, one car being loaded while the other is dumping, and all horses or locomotives are dispensed with. Fig. 19 shows the arrangement of the steam shovels and inclines as operated by one of the Chicago Canal contractors. The traveling incline is provided with a tipple very similar to those used in coal mining. The shovel first takes out a cut 8 ft. deep the full length of the excavation, as shown in Fig. 19 marked 1st cut. The next cut is carried to a depth of 15 ft. and the third cut to a depth of 20 ft. below the original ground level. After the third cut is made, the excavation is carried no deeper until by successive slices the full width of the channel has been excavated. The top lift of 20 ft. being removed, work is begun at the

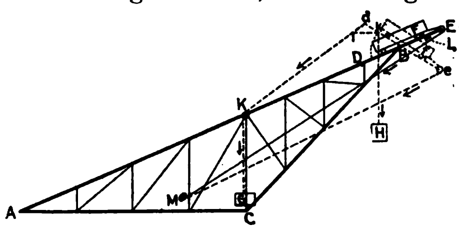



Fig. 20.

edge of the slopes of the bottom left exactly as before. In the plan, Fig. 19, the incline or conveyor 4 shows ropes for pulling the approach trestle of the incline forward; a horse whim or block and tackle to the engine being used. The engine and incline proper are carried on a car, the machinery being merely a 10 x 16-in. double cylinder hoisting engine of 75 HP. Actual experience on the Chicago Canal has proved that such an incline can handle 900 cu. yds. per 10-hr. day, day in and day out, the steam shovel being in fact the limiting factor. The trussing of the incline proper and the working of the tipple are shown in Fig. 20, in which M is a sheave around which the cable from

the engine passes to the sheave E, thence to the car; G and H are counterweights that pull the tipple back after the load is dumped. The engineman at no time sees the car, but slows up when he hears the bell rung by the car whose wheel flange strikes a bell lever near the tipple. The front wheels of the car strike a buffer L; the car stops and as the engine is still pulling on the cable, the tipple revolves, dumping the load out of the front end of the car. As the tipple revolves it pulls a wire that operates an indicator in the engine room, so that the engineer knows when to release the cable and let the tipple revolve back. The brake for controlling the descent of the car is operated by a brakeman standing on the incline where he can always see the car. Since there are two cars and two cables there are two brakemen on each incline, each man having a lever connected by wires with the brakes on the engine drum. One of these inclines complete with engines is said to cost $4,000, and the cost of operation of a steam shovel and an incline per 10-hr. shift is as follows:

| | |
|---|---|
| 4 tons of coal @ $2 | $8.00 |
| Repairs | 8.00 |
| 22 men @ $1.50 to $3 | 44.00 |
| Total | $60.00 |

Operating continuously from September, 1894, to July, 1895, on the Chicago Canal in hard clay the average output per shift on two sections was 670 cu. yds., making the cost about 9 cts. per cu. yd. not including interest and depreciation of plant. The cost of coal, labor and repairs is about equally divided between the steam shovel and the incline. One contracting firm, using 2¼-yd. shovels made cuts 20 ft. wide × 20 ft. deep, and moved each shovel forward about 13 times in 10 hrs., making a 6-ft. move each time. It took 2 mins. to move the shovel forward, and the incline with the approach trestle rigidly fastened to it was moved at

the same time. Each car held 5 cu. yds. place measure, and was filled with three shovel loads. A ¾-in. wire cable was used in hoisting and its life was 150,000 cu. yds. of material excavated, the cars being moved 350 ft. horizontally and 60 ft. vertically.

Another method of attack using a shovel and incline is shown in Fig. 21. In this case the shovel makes cuts across the axis of the canal instead of parallel with it. It will be noticed that in this case a bridge was used to dump through instead of a tipple, but this same method of shovel attack has also been used with the tipple incline just described. Using a 1½ cu. yd. shovel cuts, 15 to 20 ft. wide × 16 ft. deep were made, the shovel working for 1 hr. and then moving forward 14 ft. When a cut has been made clear across the canal, the shovel is run around the curved track, as shown at AB, while the working track is shifted close up to the face of the work. At the same time the bridge and incline are shifted by horses a distance of 20 or 25 ft., the whole time so occupied being about 50 mins. The cars used with this bridge conveyor hold 9 cu. yds. water measure, which in blasted hardpan is taken to be equivalent to 5½ cu. yds. place measure. The car has an A-shaped bottom and swinging side doors that are readily tripped, and its dead weight is 10,000 lbs. The bridge is a single track combination wood and iron Pratt truss, traveling on tracks as shown. The shovel is the limiting factor, but a maximum output of 210 car loads in 10 hrs. has been attained, although 150 car loads was the average. The force engaged on the Chicago Canal in tough clay was 1 shovel engineman, 1 cranesman, 1 fireman, 5 shovel tenders, 12 laborers breaking down face and trimming slopes, 2 men on bridge truss, 1 engineman and 1 fireman on incline, a total of 24 men besides a foreman. Two centrifugal pumps, one 8-in. and one 10-in. lifting 3,000 gallons per min. 50 ft. high were used to keep the pit drained, and in this con-

nection it should be observed that pumping cost 1 ct. to 1½ cts. per cu. yd. Work was suspended during February, March and April, and in the month of January the shovel output was 20 to 30% below the average of other months.

Fig. 22 shows an all steel incline and tipple used on one section instead of the bridge conveyor, but with the same method of shovel attack at right angles to the canal axis, shown in Fig. 21. It will be observed that there was no approach trestle used in connection with this incline, and that the engine house was on a separate flat car. The steel trusses of the incline weighed 5,800 lbs., and the total load of boilers, flat cars, etc., was 100 tons. The engines were 11 × 18-in. double Mundy, and with the boiler cost $2,700. The shovel cut was 20 ft. wide × 18 ft. deep and the best month's record was 920 cu. yds. per 10 hrs. shift, which was the best record made on the canal for a month.

# CHAPTER XIII.

## Summary and Table of Costs.

At the close of each of the seven preceding chapters we have given a rule for excavating and moving "average earth," using the different well-known methods. It now becomes desirable to tabulate the costs per cu. yd. according to each of the different rules, so that it may be seen at a glance what the relative cost is for any length of haul.

It must be remembered that there are several items of cost not included in any of these rules. These omitted items are: Cost of foreman, water boy, timekeeper, blacksmith and night watchman; interest and depreciation of plant; cost of bailing and draining; cost of grubbing and clearing; cost of spreading, trimming, rolling or ramming, and sprinkling; and cost of insuring men against accident.

In fact, as we have seen, all these items which are not included in the costs now to be given in the tables, are items of importance in every case, and in some cases they actually exceed the cost of excavating and moving the earth.

Therefore, the tables that follow must be used not blindly but with judgment; and additions must be made for these omitted items. By "average earth" we mean earth of any kind that can be plowed with one team of horses.

There are at present several rates of wages paid in different parts of the United States for common labor; 12½ cts. an hour for 10 hrs.; 15 cts. an hour for 10 hrs.; 16⅔ cts. an hour for 9 hrs., or $1.50 per 9-hr. day; 18¾ cts. an hour for 8 hrs., or $1.50 per 8-hr. day. When the word "team" is used, two horses with a driver is ordinarily meant. Team wages, are 30 cts., 35 cts., 40 cts., 45 cts. and even 50 cts. an hour in various places.

The writer has maintained teams at the following cost per month per team:

| | |
|---|---|
| ½-ton of hay @ $10 | $5.00 |
| 30 bu. oats @ 35 cts | 10.50 |
| Straw for bedding | 1.00 |
| Shoeing and medicine | 2.00 |
| Total | $18.50 |

A generation ago there were 2,000 horses used on the Brooklyn street railways. The cost of feeding each horse was $10 a month, and the depreciation in value of each horse was 25% per annum.

Contract work is not so severe as street car work, still the annual depreciation is probably not less than 15%. A team, wagon and harness costing $300 should be charged with about $60 per annum for interest and depreciation. When the team is working it must be fed oats, when not working it can be fed on hay at half the usual cost.

The following gives the average feed of horses and mules used by the H. C. Frick Coke Co., extending over a period of 6 years; 500 lbs. of hay, 7 bushels of oats, 4⅔ bushels of corn on the ear, per head per month. The daily feed of each animal was two feeds of corn, 13 ears to the feed (70 lbs. per bu.), one 6-quart feed of oats, and about 16½ lbs. of hay. Each animal averaged about 13 miles traveled per day underground, 15 miles being the maximum 10-hr. day's work. It will be observed that this feeding agrees very closely with the writer's experience.

It is not ordinarily possible to get more than 180 days of work per annum out of a contractor's team in the North, and very frequently much less. We may, therefore, say that $1.50 for each day actually worked by the team will cover its feed, interest and depreciation, for the year. If the driver is paid only while at work, then his $1.50 added to that of the team makes $3 a day for each day worked.

It will be seen that where a contractor has a large amount of teaming in sight it will ordinarily pay him to own his own teams, or at any rate enough teams to act as leaders and to "set the pace." Then, moreover, he is less likely to have strikes on his hands which is often a very important factor. But where the teaming is not extensive, jobs of short duration, and team wages reasonable, contractors usually prefer not to be bothered with teams of their own.

We shall assume in the following estimates of cost that wages are 15 cts. per hour for men, and 35 cts. per hour for team (with driver).

Engineers need not be surprised to receive bids considerably lower than prices given in the table when contractors own their own teams.

Finally, after adding all the items of cost together, it is seldom safe to add much less than 25% for profit and contingencies. We often hear of 15% profits, but it is absurd to talk of so low a profit in so uncertain a class of work as earth excavation, excepting, of course, where the contractor is thoroughly familiar with the earth from previous experience.

CONTRACT PRICES.—It is customary with many engineers to turn to the contract news columns of engineering journals when they wish to ascertain the average contract price for any particular kind of work. This is ordinarily a good check upon one's own estimates of cost, but let it not be forgotten that contract prices are often exceedingly deceptive. In the first place contractors themselves often underestimate the cost of work. Hence if the lowest bidder is much below the average of other bidders on the same work his bid should be looked upon with suspicion. In the second place contractors often "unbalance" their bids, that is they bid exceeding low upon certain items and exceedingly high on certain other items. They do this in some cases in order to

## COST OF EXCAVATING AVERAGE EARTH.

(Costs are in cents per cubic yard measured in cut, with wages at 15 cts. for man, and 10 cts. for each horse per hour; and the following items are not included: Foreman, timekeeper, blacksmith, watchman, water boy, interest and rental of plant, cost of grubbing, draining, spreading, trimming, rolling, sprinkling and insurance. For these items, see Chapter IV., and other chapters.)

| Rule. | Chapter. | Method. | Load, cu. yds. | Length of haul in ft., from cut to fill (pit to dump). 50. | 100. | 200. | 300. | 400. | 500. | 600. | 700. | Add for each 100 ft. of haul, cts. per cu. yd. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. | V. | Wheelbarrows .................... | 1/15 | 20.0 | 22½ | 27½ | 32½ | 37½ | 42½ | 47½ | 52½ | 5 |
| II. | V. | 1-horse carts (1 driver to each cart) | 1/8 | 19.0 | 19¼ | 20½ | 21¾ | 23.0 | 24¼ | 25⅛ | 26¾ | 1¼ |
| | | " " (1 driver to 2 carts).. | 1/8 | 18.9 | 18.9 | 19.8 | 20.7 | 21.6 | 22.5 | 23.4 | 24.3 | 9/10 |
| | | " " (large cart with driver) | 2/8 | 18.5 | 18.5 | 19.1 | 19.7 | 20.2 | 20.8 | 21.3 | 21.9 | 5/9 or 55/100 |
| III. | VI. | Wagons (on soft earth roads)...... | 3/4 | 18.7 | 18.7 | 19.4 | 20.1 | 20.8 | 21.5 | 22.2 | 22.9 | 7/10 |
| | | Wagons (on hard roads)........... | 1 3/10 | 18.4 | 18.4 | 18.8 | 19.2 | 19.6 | 20.0 | 20.4 | 20.8 | 4/10 |
| IV. | VII. | Drag scrapers .................... | 1/9 | 9.0 | 10.0 | 14.0 | 18.0 | 22.0 | 26.0 | 30.0 | 34.0 | 4 |
| V. | VIII. | Wheelscrapers, No. 1............. | 1/6 | 7⅛ | 8¾ | 11⅛ | 14¼ | 17.0 | 19¾ | 22⅛ | 25¼ | 2 3/4 |
| VI. | VIII. | " No. 2............. | 1/4 | 9.2 | 9.2 | 11.4 | 13.6 | 15.8 | 18.0 | 20.2 | 22.4 | 2 2/10 |
| VII. | VIII. | " (with snatch team) No. 3 | 4/10 | 9.5 | 9.5 | 10.7 | 11.9 | 13.1 | 14.3 | 15.5 | 16.7 | 1 2/10 |
| VIII. | IX. | Elevating grader with 3-horse wagons on soft earth roads..... | 1¼ | 10½ | 10½ | 10½ | 10½ | 10½ | 10½ | 11.0 | 11½ | ½ |
| IX. | XI. | Cars and horses, loaded by hand (2 cars pulled by a team)...... | 5 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 1/10 |

COST OF EXCAVATING AVERAGE EARTH.—(Continued.)

| Rule. | Chapter. | Method. | Load, cu.yds. | Length of haul in ft., from cut to fill (pit to dump). 800. | 900. | 1,000. | 2,000. | 3,000. | 4,000. | 5,000. | Add for each 100 ft. of haul, cts. per cu.yd. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I. | V. | Wheelbarrows .................... | 1/15 | 57½ | 62½ | 67½ | .... | .... | .... | .... | 5 |
| II. | V. | 1-horse carts (1 driver to each cart) | 1/3 | 28.0 | 29¼ | 30½ | 43.0 | 52½ | 65.0 | 77½ | 1¼ |
| | | " " (1 driver to 2 carts).. | 1/3 | 25.2 | 26.1 | 27.0 | 36.0 | 45.0 | 54.0 | 63.0 | 9/10 |
| | | " " (large cart with driver) | 2/3 | 22.4 | 23.0 | 23.5 | 29.0 | 34.5 | 40.0 | 45.5 | 5/9 or 55/100 |
| III. | VI. | Wagons (on soft earth roads)...... | 3/4 | 23.6 | 24.3 | 25.0 | 32.0 | 39.0 | 46.0 | 53.0 | 7/10 |
| | | Wagons (on hard roads)........... | 1 3/10 | 21.2 | 21.6 | 22.0 | 26.0 | 30.0 | 34.0 | 38.0 | 4/10 |
| IV. | VII. | Drag scrapers ................... | 1/9 | 38.0 | 42.0 | 46.0 | 86.0 | .... | .... | .... | 4 |
| V. | VIII. | Wheelscrapers, No. 1.............. | 1/5 | 28.0 | 30¾ | 33½ | 61.0 | .... | .... | .... | 2 3/4 |
| VI. | VIII. | " No. 2.............. | 1/4 | 24.6 | 26.8 | 29.0 | 51.0 | .... | .... | .... | 2 2/10 |
| VII. | VIII. | " (with snatch team) No. 3 | 4/10 | 17.9 | 19.1 | 20.3 | 32.0 | 44.0 | 56.0 | 68.0 | 1 2/10 |
| VIII. | IX. | Elevating grader with 3-horse wagons on soft earth roads..... | 1¾ | 12.0 | 12½ | 13.0 | 13½ | 18½ | 23½ | 28½ | ½ |
| IX. | XI. | Cars and horses, loaded by hand (2 cars pulled by a team)...... | 5 | 17.0 | 17.0 | 17.0 | 18.0 | 19.0 | 20.0 | 21.0 | 1/10 |

NOTE.—The foregoing is for "average earth" (readily plowed); for tougher earth, see Chapters III., VII., and others.

make their profits upon the parts of the work that they must do first, as for example the foundations of the structure. In other cases they shrewdly foresee that more rock will be encountered than the engineers have counted upon, so they bid high on rock and low on earth. In many cases they wish to conceal from other contractors what they regard as a fair price for a given kind of work, or they bid low on work apt to be subject to severe inspection in order to win the sympathy of the inspector; in such cases, of course, they bid higher on other items to make up for the loss. Finally, the engineer who takes contract prices as a guide seldom knows what the specifications were for that particular work, or what the price of labor was, or what was the length of haul, etc.

To illustrate how contractors may themselves be mistaken, we may take the deepening of the Erie Canal in 1897. The average contract price for the earthwork was 28 cts. per cu. yd. Almost without exception contractors lost money at this price, not only because labor rose from $1.25 to $1.50 a day of 10 hrs., but because the freezing of the water-soaked earth made excavation very expensive.

On the great Chicago Canal, the contract prices averaged about 27 cts. per cu. yd., wages of day laborers being about $1.50 per 10 hr. day in 1895. Most of the material was exceedingly hard, and was handled by steam shovels as described in previous chapters. The contractors made large profits on this work.

A very common bid for street grading is 25 cts. per cu. yd., while recent low bids on ditching and grading for macadam roads in Massachusetts range from 30 cts. to 50 cts. per cu. yd., the greater number being about 42 cts. Wages in Massachusetts now are about $1.75 for laborers and $4 for teams per 9 hr. day. In New Jersey, where the soil is somewhat softer and ditches are made wide and shallow, contract prices range from 15

to 40 cts., with an average of about 28 cts. per cu. yd.

Levee work in the Southern States, on the Mississippi, has often been contracted for at 12 cts. per cu. yd., it being for the most part "scraper work"; in fact one contract, in 1898, for 220,000 cu. yds. was let at 8¼ cts. in Louisiana.

In New York City, 1897, 50,000 cu. yds. of excavation for large water main trenches was let at 18 cts. per cu. yd. for the excavation plus 8 cts. for the backfill, although the average bid on these two items was 25 cts. and 17 cts. respectively.

At Quincy, Mass., 1898, 30,000 cu. yds. of trenching 8 ft. deep, for sewers, was let at 30 cts., but the average bid was 40 cts. About the same time 100,000 cu. yds. of reservoir excavation was let at Middlesex Fells, Mass., for 19 cts., while the average bid was 32 cts.

Thus we might go on indefinitely quoting actual contract prices, but we have given these not only to show the range of such prices but to show that very often the lowest bidder is far below the average of other bids. It is evident that in such cases some man has erred in his estimate, or purposely unbalanced his bid; on large earthwork jobs, however, unbalancing would seldom be done, for there are no other items of sufficient magnitude to make unbalancing an object.

We may fittingly close this subject of contract prices by saying that an engineer should never seek to stop unbalancing of bids by requiring lump-sum bids, as is now done on roadwork in New York State. Such practice inevitably leads to higher prices and not infrequently to corruption in administration of public works. Unbalancing of bids can injure no one when the engineer has so carefully examined the site of proposed excavation that he is reasonably sure of the character and quantity of each class of material that will be encountered. There is only one exception to the

foregoing statement. A dishonest contractor may bid high on the items of work that he is to do first, skim the cream, get his monthly estimate money, and leave for parts unknown. Good bondsmen are the only satisfactory safeguards against such action, but let it be said that dishonest practice of such a nature is nowadays extremely rare.

# CHAPTER XIV.

## Cost of Trenching and Pipe Laying.

There are several kinds of engineering work involving trench digging, but the most common trenches are for water pipe and for sewers. Water-pipe trenches are comparatively shallow since the top of the pipe seldom needs be more than 3 to 5 ft. below the surface of the ground to prevent freezing of the water, except possibly in small service pipes in the northern part of the United States which have been known to freeze at depths of 6 ft. Sewers being necessarily laid to true down grades, without rises and falls, are laid in trenches of varying and oft times of great depth. We shall, therefore, separate our discussion of trenching into two parts (1) Trenching for Water Pipes, and (2) Trenching for Sewers..

TRENCHING FOR WATER PIPE.—Case I. At Corning, N. Y., a trench for a 10-in. water pipe was excavated 2½ ft. wide x 5 ft. deep, x 1,500 ft. long = 600 cu. yds. in 4½ days by 24 men, or at the rate of 6 cu. yds. per man per 10-hour day, equivalent to 11 cts. a running foot or 25 cts. a cu. yd. The backfilling was done in 3 days by 2 men and 1 horse with driver, using a drag scraper and a short length of rope so that the horse worked on one side of the trench while the two men handled the scraper on the opposite side, pulling the scraper directly across the pile of earth. In this way the backfilling was made at a cost of 1.1 cts. per lin. ft. or 2½ cts. per cu. yd., there being no ramming of the back fill required. This is a remarkably low cost for backfilling, and one not ordinarily to be counted upon. The material was a loamy sand and gravel.

Case II. Rochester, N. Y., size of trench and kind of material practically the same as in Case I.

1 man excavated 8 cu. yds. a day at cost of 19 cts. cu. yd.

1 man backfilled 16 cu. yds. a day at cost of 9 cts. cu. yd.

Total cost of excavation and backfill 28 cts. cu. yd.

Case III. Alliance, Ohio. L. L. Tribus gave the following costs in Engineering News, June 14, 1894, the material being loam and clay excavated to such a depth that 4 ft. of earth would be left on top of each class of pipe after backfilling:

| | | | | | |
|---|---|---|---|---|---|
| Size of pipe in ins. | 4 | 6 | 8 | 10 | 12 |
| Wt. of pipe, lbs. per ft. | 19 | 30⅛ | 44 | 62 | 79 |
| Lbs. special per ft. | 0.4 | 0.76 | 1.1 | 1.55 | 1.9 |
| Lbs. lead per ft. | 0.4 | 0.66 | 1.0 | 1.25 | 1.5 |
| Lbs. yarn per ft. | 0.02 | 0.025 | 0.05 | 0.08 | 0.1 |
| Total length in ft. | 2,890 | 9,760 | 1,860 | 3,320 | 2,930 |

COST PER LIN. FT. LAID.

| | | | | | |
|---|---|---|---|---|---|
| Pipe | $0.2360 | $0.3780 | $0.5350 | $0.7470 | $0.9400 |
| Specials and valves | .0120 | .0189 | .0268 | .0374 | .0470 |
| Hauling | .0056 | .0078 | .0011 | .0145 | .0190 |
| Lead | .0020 | .0330 | .0500 | .0630 | .0750 |
| Yarn | .0014 | .0018 | .0035 | .0056 | .0070 |
| Trenching | .1240 | .1210 | .1287 | .1480 | .1902 |
| Pipe laying | .0370 | .0346 | .0313 | .0542 | .0463 |
| Total | $0.4360 | $0.5951 | $0.7764 | $1.0697 | $1.3245 |

This work was done by laborers and men employed by the water company and does not include cost of superintendence. The 4-ft. cover over the pipe was in some cases exceeded. The digging was comparatively easy with little ground water to bother. Mr. Tribus has kindly given the writer a statement of the wages paid, which were: Laborers, $1.25; pipe handlers, $1.50; and calkers, $2.25 per 10-hour day.

Case IV. "G. S. W. '88" in The Technic of 1896, gives the following, the material in all cases being clay: Wages of laborers 15 cts., pipe handlers 16 to 17½ cts., foreman 20 cts. per hour; depth of trench 4 to 5½ ft.:

| Example | A | B | C | D |
|---|---|---|---|---|
| Size of pipe, ins. | 24 | 24 | 12-16 | 10 |
| Length of pipe, ft. | 2,550 | 2.200§ | 6,241 | 8,969 |
| Excavation, cu. yds. | 2,710 | 1,963 | 3,441 | 4,508 |
| Surplus earth,* cu. yds. | 1,300 | 862 | 1,030 | ..... |
| Cost of excavation per ft. | $0.2725 | $0.333 | $0.2061 | $0.2416 |
| " " pipe laying per ft. | .2480 | .182 | .2089 | .0939 |
| " " bell holes per ft. | .1500 | .128 | .0954 | .0098 |
| " " backfilling, per ft. | .1790 | .191 | .1228 | .1360 |
| " " ramming per ft. | .7927† | .107‡ | .2896† | .1322† |
| " " tile, hose work, per ft. | ..... | ..074 | ..... | .0200 |
| " " load'g excess earth, ft. | .0895 | .046 | .0358 | .0025 |
| " " cart'g excess earth, ft. | .0636 | .055 | .0635 | .0046 |
| Total labor cost per ft. | $1.7953 | $1.116‡ | $1.0318‡ | $0.6433 |
| Cost of excavation, cu. yd. | 0.2562 | 0.373 | .3736 | .4807 |
| " " backfilling, cu. yd. | 0.1684 | 0.216 | .2226 | .2706 |
| " " ramming, cu. yd. | 0.7461† | 0.121‡ | .5434† | .8618† |
| " " tile, hose work, cu. yd. | ..... | 0.084 | ..... | ..... |
| Swell'g of mater'l on loosen'g. | 44% | 30 to 44½%* | 20% | ..... |

*This surplus earth was hauled away in wagons, after filling the trenches and leaving a 4-in. crown to provide for settlement.

§1,400 ft. of this trench was back-filled without ramming, using water instead; ramming, however, was much more effective in compacting the clay.

†Rammed dry in 4-in. layers.

‡Rammed wet; the portion that was rammed dry cost $1.40 per ft. total.

‡This total does not check with the items, so there must be an error somewhere.

With labor at $1.25 for 8 hours and material clay as before, streets paved with wood. "G. S. W." also gives the following:

| Example | E | F | G | H |
|---|---|---|---|---|
| Size of pipe in ins. | 12 | 12 | 10 | 8 |
| Depth of trench, ft. | 5 | 5 | 5 | 5 |
| Length of trench, ft. | 1,048 | 2,475 | 2,592 | 2,049 |
| Cost of excavation per ft. | $0.186 | $0.134 | $0.1920 | $0.1442 |
| " " pipe laying per ft. | .257 | .162 | .1218 | .0678 |
| " " backfilling, per ft. | .450 | .390 | .3949 | .3632 |
| " " hauling surplus per ft. | .014 | .011 | .0101 | .0194 |
| Total labor cost per ft. | $0.907 | $0.697 | $0.7188 | $0.5746 |

The two most striking features in the foregoing data are (1) the enormous swelling of the clay upon loosening and casting it out of the trenches, and (2) the extraordinary high cost of ramming the clay in backfilling. It is difficult to explain either of these items except upon the assumption that the loosened clay dried out when exposed to the sun and air, forming hard rock-like clods which no amount of ramming seems to have consolidated effectually. Adding water as in Exam-

ple B seems to have had no very good effect in consolidating the backfill, although it was less expensive than ramming. But it is a well-known fact that water makes dry clay swell, and it does not cause layers of hard lumpy clay to settle in a trench except as a result of weeks of slow seepage of rains.

It will be noted that all this work was extraordinarily expensive. Even the pipe laying cost double that given in Case II., which is a fair average. We may infer that this work was not done by contract but by day labor for a municipality or a company, and that the foreman did not secure "a day's work" from the men—which is so often the case in municipal day-labor work.

Case V. In Engineering News, June 28, 1890, Mr. E. B. Weston, Engineer Water Department, Providence, R. I., gives the fullest records of pipe laying cost, based upon actual experience, of which we have any knowledge. The following tables are given by him and are based upon many miles of trench work:

EASY DIGGING, SAND.

| Size of pipe, ins.... | 4 | 6 | 8 | 10 | 12 | 16 | 20 |
|---|---|---|---|---|---|---|---|
| 1. Trenching* ...... | .0422 | .0518 | .0611 | .0707 | .0798 | .1445 | .2088 |
| 2. Laying .......... | .0129 | .0162 | .0191 | .0219 | .0249 | .0370 | .0497 |
| 3. Foreman ........ | .0130 | .0158 | .0188 | .0216 | .0244 | .0303 | .0360 |
| 4. Tools, etc.... ... | .0041 | .0050 | .0059 | .0069 | .0078 | .0134 | .0191 |
| 5. Calking .... ..... | .0106 | .0107 | .0108 | .0111 | .0118 | .0159 | .0301 |
| 6. Lead, 5 cts. lb... | .0224 | .0320 | .0431 | .0553 | .0683 | .0950 | .1203 |
| 7. Teams .... ...... | .0070 | .0090 | .0115 | .0136 | .0160 | .0203 | .0216 |
| 8. Carting .... ..... | .0078 | .0149 | .0208 | .0275 | .0340 | .0518 | .0746 |
| 9. Total.... .. ..... | .1200 | .1554 | .1911 | .2286 | .2676 | .4082 | .5602 |

MEDIUM DIGGING, GRAVEL, ETC.

| Size of pipe, ins. | 4 | 6 | 8 | 10 | 12 | 16 | 20 | 24 |
|---|---|---|---|---|---|---|---|---|
| 1. Trenching*. | .0597 | .0697 | .0790 | .0883 | .0974 | .1700 | .2400 | .3019 |
| 2. Laying .... | .0189 | .0220 | .0249 | .0279 | .0307 | .0440 | .0577 | .0639 |
| 3. Foreman .. | .0180 | .0206 | .0234 | .0265 | .0294 | .0350 | .0373 | .0396 |
| 4. Tools, etc.. | .0056 | .0065 | .0075 | .0084 | .0093 | .0154 | .0214 | .0602 |
| 5. Calking. .. | .0106 | .0107 | .0108 | .0111 | .0118 | .0159 | .0301 | .0757 |
| 6. Lead, 5c. lb. | .0224 | .0320 | .0431 | .0553 | .0683 | .0950 | .1203 | .1600 |
| 7. Teams ..... | .0070 | .0090 | .0115 | .0136 | .0160 | .0203 | .0216 | .0228 |
| 8. Carting ... | .0078 | .0149 | .0208 | .0275 | .0346 | .0518 | .0746 | .1317 |
| 9. Total .... .. | .1500 | .1854 | .2210 | .2586 | .2975 | .4474 | .6030 | .8630 |

*Including backfilling, and in all cases the depth of the trench was such that the center of the pipe was 4 ft. 8 ins. below ground surface.

HARD DIGGING, HARD OR MOIST CLAY.

| Size of pipe, ins.... | 4 | 6 | 8 | 10 | 12 | 16 | 20 |
|---|---|---|---|---|---|---|---|
| 1. Trenching* | .0860 | .0959 | .1053 | .1147 | .1300 | .2261 | .3264 |
| 2. Laying | .0271 | .0303 | .0333 | .0362 | .0411 | .0530 | .0669 |
| 3. Foreman | .0260 | .0286 | .0314 | .0343 | .0372 | .0428 | .0452 |
| 4. Tools, etc. | .0081 | .0090 | .0099 | .0109 | .0118 | .0201 | .0283 |
| 5. Calking | .0106 | .0107 | .0108 | .0111 | .0118 | .0159 | .0301 |
| 6. Lead, 5 cts. lb... | .0224 | .0320 | .0431 | .0553 | .0683 | .0950 | .1203 |
| 7. Teams | .0070 | .0090 | .0115 | .0136 | .0160 | .0203 | .0216 |
| 8. Carting | .0078 | .0149 | .0208 | .0275 | .0346 | .0513 | .0746 |
| 9. Total | .1950 | .2304 | .2661 | .3036 | .3508 | .5250 | .7134 |

Wages in all cases above were $1.50 a day for laborers trenching (1) and laying (2), $3 a day for foreman (3), $2.25 for calkers (5), and $2.25 for teams (7) which probably refers to team without driver. Carting (8) was in all cases $1 a ton. Allowance for tools (4) was made on a basis of 7.2% of items (1) and (2).

| Tap and stop. | | Lead service pipe per lin. ft. | | |
|---|---|---|---|---|
| Diam. in ins. | Tap, stop, etc., including tapping. | Diam. in ins. | Weight in lbs. | Cost of pipe, trenching, laying, etc. |
| ⅜ | $6.00 | ½ | 3.00 | $0.34 |
| ½ | 6.23 | ⅝ | 4.00 | .40 |
| ⅝ | 6.81 | ¾ | 4.75 | .45 |
| ¾ | 8.67 | 1 | 6.00 | .52 |
| 1 | 10.71 | 1¼ | 9.00 | .70 |
| ... | ..... | 1½ | 10.00 | .76 |

In the above, lead pipe was assumed at 6 cts. per lb.; labor of trenching and laying, 16 cts. per ft.

Short lengths, 15 to 50 ft., of 6-in. pipe cost 34 cts. per ft. in easy digging to 45 cts. in hard digging for excavation, laying and backfilling, wages being as above stated.

The trench for a 24-in. pipe, 19,416 ft. long and 6.6 ft. deep cost 32 cts. per cu. yd. for excavation and backfill, with wages at $1.50 a day.

A 48-in. main was laid for $1.65 per ft. including digging, laying, calking and backfilling.

A 16-in. pipe, 374 ft. long passed under two railway tracks, and the cost of trenching, laying and backfilling was 50 cts. per ft.

An 8-in. pipe was laid across a bridge, and the cost of boxing, laying pipe, etc., was $1.32 per ft., while for a 12-in. pipe the cost was $1.50 per ft.

*Including backfilling, and in all cases the depth of the trench was such that the center of the pipe was 4 ft. 8 ins. below ground surface.

Trenches were ordinarily 2 ft. wider than the pipe and 5 ft. plus half the diameter of the pipe deep. Such trenches were dug, the pipe laid and backfilling made at the following rate per laborer engaged:

| | | | |
|---|---|---|---|
| 6-in. pipe, | easy earth .. | 21.0 | lin. ft. per day. |
| 6-in. " | medium earth | 17.2 | " " " " |
| 6-in. " | hard earth .. | 10.3 | " " " " |
| 8-in. " | easy earth .. | 19.3 | " " " " |
| 12-in. " | medium earth | 13.4 | " " " " |
| 20-in. " | easy earth .. | 9.0 | " " " " |
| 24-in. " | medium earth | 4.4 | " " " " |

Earth excavation in trenches where digging is easy costs 20 cts. per cu. yd.; rock excavation averages $2 per cu. yd. and runs as high as $3, wages being $1.50 a day for labor.

Case VI. In Engineering News, March 30, 1893, Mr. C. D. Barstom gives very complete tables of cost of shallow trenching and pipe laying in a southern city, where negro laborers were used. From the data given by him we have compiled the following tables of cost:

TABLE OF COST OF TRENCHING AND PIPELAYING IN THE SOUTH.

Wages, per 10-hr. day for negro laborers, $1.25; for calkers, $1.75; for white foremen, $3; for teams, $3.25; for horse ridden by boy, $1.50.

| Job | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Pipe, ins. | 10[1] | .... | 6 | 8 | 10 | 8[8] |
| Length, ft. | 11,000 | 6,000 | 6,215 | 11,352 | 2,636 | 21,856 |
| Width trench, ft. | 2 | .... | .... | .... | .... | .... |
| Depth trench, ft. | 3.5 | 3 | 3 | 3 | 3 | 3 |
| Material | ....[2] | ....[4] | .... | .... | .... | ....[9] |
| No. laborers digging | 33 | 30 | 40 | 31 | 45 | 46 |
| No. teams plowing | .... | .... | .... | 3½ | 5 | 2½ |
| Team time, cts. per ft. | .... | .... | .... | 0.80 | 0.62 | 0.60 |
| Labor, digging, cts., ft. | 6.66 | 2.74 | 5.19 | 2.68 | 2.12 | 4.00 |
| Foreman, digg'g, cts., ft. | 0.50 | 0.23 | 0.31 | 0.21 | 0.12 | 0.20 |
| Labor, pipe lay'g, cts., ft. | 2 04 | .... | 0.68 | 0.77 | 0.94 | 1.12 |
| Formn, pipe layg cts. ft. | 0.39 | .... | 0.17 | 0.21 | 0.18 | 0.24 |
| Bell hole digging, cts., ft. | 2.70 | .... | 0.77 | 0.98 | 0.93 | 1.16 |
| Bell hole digging, foreman, cts. per ft. | 0.27 | .... | 0.16 | 0.21 | 0.18 | 0.18 |
| Calking, cts. per ft. | 1.30 | .... | 0.52 | 0.64 | 0.63 | 0.75 |
| Backfill and tamp: | | | | | | |
| Labor, cts., per ft | 4.32[3] | 1.00[5] | 1.01[6] | 2.09 | 1.42[7] | 0.95[9] |
| Foreman, cts., per ft. | 0.36 | 0.22 | 0.22 | 0.32 | 0.18 | 0.18 |
| Team,* cts., per ft. | .... | .... | 0.36 | .... | .... | 0.41 |
| Horse rid'n by boy, cts., ft | .... | .... | 0.07 | .... | 0.09 | .... |
| Total cost, cts., per ft. | 18 54 | 4.19 | 9.46 | 8.91 | 7.41 | 9.79 |

*Backfill with drag scraper.

[1]Trenching in an old street, 1,200 ft. in very muddy ground. Two rainy spells in 18 days of work. Then 10-in. pipe was laid

For the most part the trenches were 15-ins. wide at bottom and 20 ins. at top, and 3 ft. deep. Some trenching was done using a team on a drag scraper, 20-ins. wide; then the trench was made 3 ft. wide at top. Using teams was more economical, as may be seen by comparing C with D in the foregoing table. After a rain, however, the scrapers could not be used to advantage. In using a plow for loosening the earth, several feet of chain are fastened to the end of the plow beam, and one or more men ride the beam; in this way plowing may be done in a trench 4 ft. deep, one horse walking on one side and one on the other side of the trench. A blacksmith was kept busy sharpening about 60 picks a day. There was a night watchman. The pipe was distributed by contract at 34 cts. per ton.

The lead and yarn consumed per ft. of pipe (length 12 ft.) was:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.3 | lbs. | of | lead | and | .04 | lb. | of | hemp | for | 12-in. | pipe. |
| .96 | " | " | " | " | .04 | " | " | " | " | 10-in. | " |
| .95 | " | " | " | " | .03 | " | " | " | " | 8-in. | " |
| .66 | " | " | " | " | .02 | " | " | " | " | 6-in. | " |

Some 6,000 ft. of 2-in wrought-iron service pipe was laid in trenches 2 ft. deep, at a cost of 1.9 cts. for trenching, 0.24 ct. for laying pipe, and 0.71 ct. for backfilling—there was no tamping done.

For a distance of 373 ft. a trench 2 ft. wide and 3 ft. deep passed through a street paved with brick

for 3,440 ft.; then 4,038 ft. of 12-in. pipe was laid for 1¼ cts. per ft. less than it cost for the 10-in. pipe; then 3,270 ft. of 8-in. pipe was laid for 2¼ cts. per ft. less than it cost for the 10-in.

[2]Cemented clay and gravel requiring hard picking. Frequent rains.

[3]The backfilling and tamping were done most thoroughly, a stretch of 2,550 ft. requiring 3 days for 30 men.

[4]Sand and loam, bottom land, very easy digging.

[5]Very easy shoveling and no tamping; 11 men 7 days backfilled 9,620 ft. of trench.

[6]Dragscrapers used to backfill; boy riding horses to tamp, gang 22 men, 3 teams, 1 boy and horse, 2 days on 5,447 ft.

[7]Backfilled 1,670 ft. in one day by 19 men, using 1 boy and horse on tamping.

[8]Half the pipe was 8-in. at cost here given, half was 6-in., costing ½-ct. less per ft. for laying.

[9]Ground wet and often muddy. Backfilling 11,433 ft. done by 12 men and 2 teams on scrapers in 7 days; no tamping.

laid on $7\frac{1}{2}$ ins. of concrete. The brick was removed for a width of 3 ft. and the cost was as follows:

| | | Men, days. | Cts. per lin. ft. |
|---|---|---|---|
| Removing brick and concrete...... | Foreman | 0.5 | |
| | Laborers | 7.0 | 2.61 |
| Excavating trench .... .... ...... | Foreman | 0.5 | |
| | Laborers | 18.0 | 6.30 |
| Backfilling and tamping well...... | Foreman | 1 0 | |
| | Laborers | 10.6 | 4.09 |
| Labor relaying concrete.................... | | 7.8 | 2.61 |
| " " bricks.... ..... ............ | | 4.5 | |
| Professional brick pavers.......... ........ | | 4.0 | 4.59 |
| " " " helpers.... .... ...... | | 2.0 | |
| Hauling away 23 loads surplus earth......... | | | 1.23 |
| 15 cu. yds. of sand cushion.................. | | | 4.02 |
| 1,700 new bricks....... .................... | | | 6.92 |
| 18½ bbls. cement to relay concrete.......... | | | 6.20 |
| Total...... ...... ... .................. | | | 38.58 |

## Trenching for Sewer Pipe.

Case VII. In Engineering News, Aug. 20, 1896, Mr. H. N. Ogden, C. E., gives the following costs of trenching and laying 8-in. sewer pipe in Ithaca, N. Y.: The column of labor cost is based on daily wages of \$1.35 for laborers, \$1.50 for pipe layers, and \$2 for foreman. Mr. Ogden

| Name of street. | Length laid. | Depth of trench in ft. | Material. | No. of days work. | Cost of labor. Total. | Cost of labor. Per ft. |
|---|---|---|---|---|---|---|
| Wheat ...... | 1,134 | 5.3 | 1 | 4 | \$126.50 | \$0.11 |
| Corn ....... | 1,504 | 5.8 | 2 | 5 | 200.70 | .12 |
| Washington . | 398 | 4.9 | 3 | 1½ | 49.50 | .12 |
| Titus ....... | 1,391 | 6.8 | 4 | 4½ | 318.90 | .23 |
| Plain ....... | 1,332 | 5.9 | 5 | 7 | 209.00 | .16 |
| Buffalo ..... | 597 | 6.7 | 6 | 4 | 108.25 | .18 |
| Fayette ..... | 984 | 5.6 | 7 | 4 | 195.05 | .20 |
| Centre ...... | 1,334 | 6.8 | 8 | 7 | 347.00 | .26 |
| Green ...... | 1,919 | 5.7 | 9 | 11 | 418.85 | .22 |
| Clinton ..... | 2,403 | 5.4 | 10 | 11 | 519.85 | .22 |
| Albany ..... | 1,431 | 5.0 | 11 | 9 | 319.50 | .22 |
| Geneva ..... | 1,323 | 5.3 | 12 | 7 | 373.47 | .28 |
| Cayuga ..... | 1,413 | 6.3 | 13 | 10 | 468.25 | .33 |

[1]Wet clay; water 3 ft. down, bailed out.
[2]Wet clay; water 3 ft. down, bailed out, occasional bracing.
[3]Wet clay.
[4]Loam over wet clay; water 6 ft. down; occasional bracing.
[5]Wet clay; water 5 ft. down; diaphragm pump; occasional bracing.
[6]Clay and gravel; much water in places; pump; braced.
[7]Wet clay; water 4 ft. down; occasional bracing and pumping.
[8]Wet clay; water 3 ft. down; 1 diaphragm; occasional bracing.
[9]Half clay, half gravel; half close sheeted; underdrain pumps.
[10]Wet clay, some gravel pockets; 1 pump; some bracing.
[11]Gravel containing water at 5 ft; pump; half sheeted.
[12]Sheeting and pumping entire; water at 5 ft.
[13]Loose gravel; brick pavement removed; half braced and half sheeted.

has kindly informed the writer that the working day was 10 hours long. Teams were paid \$3.50, masons on manholes \$3.50 and masons' helpers \$1.50, 8-in. sewer pipe cost 12½ cts. per ft. Natural cement, at 95 cts. per bbl., laid 120 to 243 ft. of pipe per bbl. The work was by contract, and not all under the same foreman; hence the variation in cost shown in the following table:

Case VIII. In Engineering News, March 30, 1893, Mr. Geo. G. Earl, C. E., gives the cost of some pipe sewer work at Cardele, Georgia. Wages were 80 cts. to \$1 per day for labor (presumably negroes) and the foreman received \$70 a month.

| Size of pipe. | Depth of cut in ft. | Length in ft. | Cost of labor cts. per ft. | Cost of foreman cts. per ft. |
|---|---|---|---|---|
| 8 inches.... ...... ..... | 5.9 | 1,185 | 14.1 | 1.0 |
| 8 inches.... ...... ..... | 7.0 | 3,090 | 22.8 | 1.9 |
| 8 inches.... ...... ..... | 8.0 | 900 | 33.8 | 1.9 |
| 8 inches.... ...... ..... | 11.2 | 487 | 35.2 | 5.8 |
| 10 inches.... ...... ..... | 7.0 | 225 | 26.7 | ... |
| 10 inches.... ...... ..... | 7.1 | 298 | 35.5 | 1.6 |
| 12 inches.... ...... ..... | 5.4 | 1,044 | 27.0 | 1.1 |
| 18 inches.... ...... ..... | 6.7 | 963 | 33.5 | 1.7 |
| 18 inches.... ...... ..... | 10.6 | 867 | 79.2 | 4.0 |

The "Cost of Labor" given in the fourth column includes trenching, pipe laying and backfilling.

In building 2.6 miles of sewer (2 of which was 8-in.) and 35 manholes, the total cost was:

| | | | |
|---|---|---|---|
| Labor .................. | \$3,867 | Brick........ ........... | \$252 |
| Masons and helpers.. ... | 462 | Cement...... ... ...... | 166 |
| Sundries.. ...... ...... | 17 | Hauling.... ... ....... | 82 |
| Foreman.... ... ...... | 266 | Manhole covers ......... | 289 |
| Supervision .... ........ | 1,000 | Tools and incidentals.... | 561 |
| | | Total.... ........ .. | \$9,591 |

Case IX. In Engineering News, Jan. 28, 1897, Mr. A. D. Thompson, City Engineer, gives some valuable data of deep and wide trench work at Peoria, Ill. The trenching given in the preceding eight cases was in all cases narrow work, and as a consequence each man loosened and shoveled much less earth than is the case in wider trench work. Moreover the side trimming of narrow trenches forms a much greater element of cost per cu. yd. than in wider trenches.

The work at Peoria was by contract. Mr. A. W. Gates, Engineer for the Contractors, gave the following as recorded by Mr. Thompson:

COST OF SHEETING.—On a trench 13 ft. wide × 45 ft. deep, sheeting in 16-ft. lengths cost as follows for labor:

| | |
|---|---|
| 2 Men on top, at $2 | $4 |
| 2 Men setting sheeting, at $2.50 | 5 |
| 8 Men driving sheeting, at $1.50 | 12 |
| 8 Men pulling sheeting, at $1.50 | 12 |
| 2 Men moving lumber ahead, at $1.50 | 3 |
| Total daily wages of gang | $36 |

This gang sheeted 12 lin. ft. of trench per day at a cost of $3 per lin. ft., all work being by hand; this is equivalent to 6⅔ cts. per lin. ft. of trench for each foot of depth. If 2-in. sheet plank were used, there were 192 ft. B. M. of sheet plank per lin. ft. of trench and probably 38 ft. B. M. of stringers and braces, say 230 ft. B. M. per lin. ft. From which we see that driving and pulling sheeting, including bracing, cost for labor about $13 per M. (= 1,000 ft. B. M.) at the rate of wages above given, which is a high cost.

The cost of exactly the same kind of work, using an Adams' trench machine with steam power for driving and pulling the sheeting, was as follows:

| | |
|---|---|
| 2 Timber men on top, at $2 | $4.00 |
| 2 Men setting, at $2.50 | 5.00 |
| 1 Man operating driver | 2.00 |
| 2 Helpers, at $1.50 | 3.00 |
| 1 Man pulling | 2.00 |
| 2 Helpers, at $1.50 | 3.00 |
| 1 Engineer | 2.00 |
| 1 Man moving lumber ahead | 1.50 |
| Coal, oil, steam hose and repairs | 2.50 |
| Total | $25.00 |

Twelve lineal feet of trench, 45 ft. deep, were timbered per day at this cost of $25, or at $2.08 per lin. ft., which is practically ⅔ the cost by hand above given, and in addition the wear of the sheet plank was less than with hand driving.

The following cost of sheeting is for hand work, trench being 12 ft. wide × 35 ft. deep:

| | |
|---|---|
| 2 Timber men on top, at $2 | $4.00 |
| 1 Man setting | 2.50 |
| 6 Men driving, at $1.50 | 9.00 |
| 4 Men pulling, at $1.50 | 6.00 |
| 1 Man moving lumber | 1.50 |
| Total | $23.00 |

At this cost, 13 lin. ft. of trench were sheeted per day, or at the rate of $1.77 per lin. ft.

Smaller trenches, 8 ft. to 16 ft. deep in sand, cost from 10 to 25 cts. per lin. ft. for labor of sheeting with 2 × 8-in. hemlock. Stringers in trenches 35 ft. or more deep were 8 × 8 ins. yellow pine, with 6 × 8-in. white pine braces. In trenches of less depth 6 × 6-in. hemlock stringers and braces were used. The above costs do not include wear and tear on timber. Some sewer contractors figure on using hemlock sheeting about 4 times, with hand-driving, before it is worn out.

COST WITH ADAMS TRENCH MACHINE.—This machine consisted of a series of wrought-iron, ∩-shaped bents, the lower feet of the ∩ being provided with wheels running on rails laid each side of the trench. These ∩ bents carried two rails, on each side, beneath the top of the bent, and a car ran along these rails; this car was pulled back and forth by cables from a hoisting engine at one end of the trench; and the same engine raised buckets up to the car where they

[illegible] the following was the cost in a trench 12 ft. wide × 25 ft. deep.

| | |
|---|---|
| 18 Men handling buckets at $1.50 | $27.00 |
| 1 Man operating bucket car | 2.00 |
| 1 Foreman | 3.00 |
| 1 Engine man | 2.50 |
| 1 Water boy | .50 |
| Coal, oil, etc. | 1.00 |
| Total | $36.00 |

This force excavated 284 buckets of 1 1/9 cu. yds. each, or 316 cu. yds., daily at a cost of 11.4 cts. per cu. yd. It is not stated whether this was loose measure in buckets or place measure.

The same gang operating in a trench, 12 ft. wide × 33 ft. deep, averaged 288 buckets a day, at a cost of 12.5 cts. per cu. yd. It is not stated, but it is presumable, that most of the excavated material was dumped directly from the buckets as backfill into the trench where the sewer was completed.

A Moore Hoister and Conveyor, which differed only in having the bucket car travel on top of the bent, instead of below, required one more man handling the buckets, making the daily force account $38. In a trench 12 ft. wide × 35 ft. deep the Moore machine daily averaged 286 buckets of 1 cu. yd. each, at a cost of 13.3 cts. per cu. yd.

## Types of Trench Machines.

From the discussion of Case IX, just preceding, we have been lead to a consideration of trench machines. There are four types of these machines commonly used: (1) The traveling derrick, or locomotive crane; (2) The bucket car traveling on a trestle; (3) The bucket traveling on a trolley suspended from a wire cable supported from towers; and (4) The bucket traveling on a trolley suspended from a rigid track supported by trestle bents.

Undoubtedly type (1), the traveling derrick, was the first kind of trench machine used. The rails upon which the wheels of such a derrick travel may either straddle the trench or be both on one side. If there is room in the street, and there usually is in any but the heavily traveled streets of large cities, the writer prefers laying the track off to one side of the trench.

For a comparatively small job, the contractor can readily make a traveling derrick by mounting a small derrick and double-drum hoisting engine on a platform car. Buckets or skips loaded by hand are used after the trench gets to be over 5 ft. deep, the derrick raises these buckets swings them to one side and they are dumped into one-horse dump carts, the material being thus hauled back a few hundred feet and used for backfill, or the excess hauled away and wasted. The derrick is moved forward as the work progresses by hitching a rope to a tree or other anchorage ahead and passing it around the winch head of the engine.

When the work becomes large enough to warrant the outlay for plant, a small traveling derrick —one that actually travels back and forth—may be purchased. There is perhaps no single machine for earth moving, masonry work, etc., so universally useful as such a traveling derrick or locomotive crane. As stated in an earlier chapter, such a locomotive crane provided with a clam-shell bucket makes a good steam shovel or dredge in material not very hard or rooty, and is decidedly useful in loading sand, broken stone, etc., from stock piles into wagons or cars. Locomotive cranes are made by the American Hoist & Derrick Co., of St. Paul, Minn.; The Brown Hoisting Machinery Co., of Cleveland, Ohio; Industrial Works, Bay City, Mich., and others, whose catalogue illustrate and describe these cranes in detail.

A locomotive crane handling buckets loaded by hand is evidently limited to a large extent by the number of men shoveling in the trench, so it is

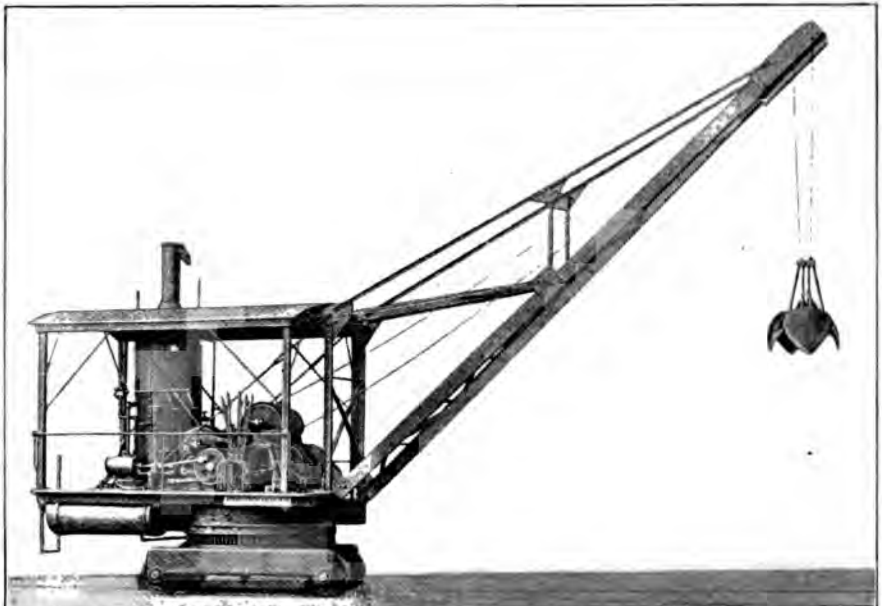


Fig. 23. The Locomotive Crane With Orange-Peel Bucket.

seldom safe to count upon more than 125 to 150 cu. yds. of earth handled daily by the crane, particularly where it travels 200 ft. or more with each bucket back to the dump where the backfill is being made. Since a locomotive crane can swing a full circle, even while traveling along the track, it can be used also to deliver and pull the sheeting.

Regarding the second type of trench machine, that in which a bucket car travels on an elevated track or trestle over the trench, we may take the Moore or the Potter machines as standards.

The Potter Mfg. Co., of Indianapolis, Indiana, makes a machine of undoubted merit. The trestle extends over 272 ft. of trench, and a bucket car carrying two buckets rides on tracks on top of the trestle bents. This car is moved back and forth by a stationary hoisting engine, mounted on trucks at one end of the trestle; this same engine also raises the buckets, which are held, when raised, by clutches on the bucket car.

The same company makes a modified form of bucket car that travels on rails laid on the ground, the car being mounted on stilt-like legs at each of its four corners, so that its body will clear any projecting sheeting planks. This surface car is especially recommended wherever sewer lines are short, or where frequent turns are made in the line of the trench, for any trestle machine has to be entirely taken apart to get around a curve, while a surface machine works well on curves.

The third type of trench machine, in which buckets travel on a trolley along a cable, is especially adapted for city work where all possible obstructions to traffic must be avoided, and especially where the trench is so wide that a trestle bent cannot be well made to span the trench. Two A-shaped bents or towers, 20 to 35 ft. high, and 200 to 300 ft. apart, support the $1\frac{1}{2}$-in. cable along which the bucket travels. A hoisting engine at one end with two $7 \times 10$-in. cylinders, and capable of lifting 5,000 lbs., raises and transports the buckets at a

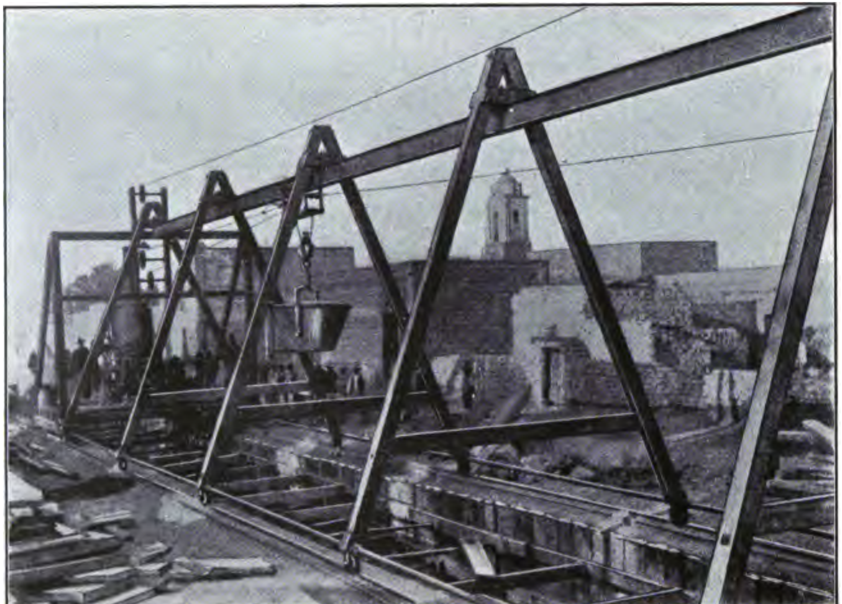


Fig. 24. Carson Trenching Machine.

speed of 440 ft. a minute, or 5 miles an hour. The following data have been obtained from The Carson Trench Machine Co., of Charlestown, Boston, Mass., makers of the Carson-Lidgerwood cableway much used on the Rapid Transit Subway, New York City:

Aside from the men required to fill the buckets, the force required consists of an engineman, a fireman, a signalman, and a dumpman; and $\frac{1}{3}$ to $\frac{1}{2}$ ton of coal is daily consumed. On a sewer in Orange, N. J., 44 buckets (1 cu. yd.) were handled per hour on an average, 60 being the maximum. The output depends upon the number of men digging, and the character of the material, but 250 cu. yds. a day may be taken as a good output.

The following costs are given in letters to the Carson Trench Machine Co.:

Mr. Frank P. Davis, C. E., gives the following for a sewer in Washington, D. C.; Width of trench 18 ft.; depth at which cableway began work, 15 ft.; distance of travel of 1 cu. yd. bucket, 150 ft.; number of trips per hour, 35; hours per day, 8; material, cemented gravel. Cost:

| | |
|---|---|
| Engineman | $2.00 |
| Fireman | 1.25 |
| Signalman | 1.00 |
| 2 Dumpers, at $1 | 2.00 |
| Coal, oil and waste | 1.50 |
| Interest and maintenance (estimated) | 7.00 |
| | $14.75 |
| 30 Men picking and shoveling | 30.00 |
| Total for 280 cu. yds. | $44.75 |

Cost of picking, shoveling, hoisting 15 ft. and conveying 150 ft. to wagons, 16 cts. cu. yd. (Note that the wages were very low.) Bracing and sheeting was going on at the same time; the men did not know they were being timed.

Fig. 25.

James Pilkington, of New York, says: "I have excavated and refilled 250 cu. yds. in 10 hours at an expense of 15 cts. per yard. For rock excavation the cableway has no equal. I have taken the machine down and moved 250 ft., and put up, and was in working order in three hours and fifty minutes. (This is unusually fast; it generally takes two days with 15 men.)

The fourth type of trench machine, in which a trestle and track replaces the cableway, is also made by the Carson Trench Machine Co., and is probably to be preferred to the cableway for trenches less than 12 ft. wide, since there are no towers with heavy anchorages to be provided as for the cableway.

The legs of the A-bents are provided with wheels at the bottom riding on a track straddling the trench, and the whole trestle can be moved forward in 5 to 10 mins., from time to time, as the work advances without taking the trestle apart, unless a curve has to be rounded. These A-bents are of 6 x 8-in. spruce, 20 ft. high and have a spread of 18 ft. at the bottom. The engine is the same as for the cableway machine. The trestle is 288 ft. long, and buckets of 1 cu. yd., each are handled. The crew and the cost of operation are the same as for the cableway.

Mr. A. W. Byrne states that in completing one 4,000-ft. section of the Metropolitan sewer system, at Boston, he used the following force:

| | |
|---|---|
| 1 Engineman | $3.00 |
| 1 Lockman | 2.00 |
| 1 Dumper | 1.50 |
| 8 Shovelers, at $1.75 | 14.00 |
| 2 Bracers, at $2.50 | 5.00 |
| 2 Tenders, at $2.00 | 4.00 |
| 4 Plank drivers, at $2.00 | 8.00 |
| 2 Men cutting down planks, at $2.00 | 4.00 |
| 8 Men pulling planks, etc., at $1.75 | 14.00 |
| Total | $55.50 |

The work at Peoria was by contract. Mr. A. W. Gates, Engineer for the Contractors, gave the following as recorded by Mr. Thompson:

COST OF SHEETING.—On a trench 13 ft. wide × 45 ft. deep, sheeting in 16-ft. lengths cost as follows for labor:

| | |
|---|---|
| 2 Men on top, at $2 | $4 |
| 2 Men setting sheeting, at $2.50 | 5 |
| 8 Men driving sheeting, at $1.50 | 12 |
| 8 Men pulling sheeting, at $1.50 | 12 |
| 2 Men moving lumber ahead, at $1.50 | 3 |
| Total daily wages of gang | $36 |

This gang sheeted 12 lin. ft. of trench per day at a cost of $3 per lin. ft., all work being by hand; this is equivalent to 6⅔ cts. per lin. ft. of trench for each foot of depth. If 2-in. sheet plank were used, there were 192 ft. B. M. of sheet plank per lin. ft. of trench and probably 38 ft. B. M. of stringers and braces, say 230 ft. B. M. per lin. ft. From which we see that driving and pulling sheeting, including bracing, cost for labor about $13 per M. (= 1,000 ft. B. M.) at the rate of wages above given, which is a high cost.

The cost of exactly the same kind of work, using an Adams' trench machine with steam power for driving and pulling the sheeting, was as follows:

| | |
|---|---|
| 2 Timber men on top, at $2 | $4.00 |
| 2 Men setting, at $2.50 | 5.00 |
| 1 Man operating driver | 2.00 |
| 2 Helpers, at $1.50 | 3.00 |
| 1 Man pulling | 2.00 |
| 2 Helpers, at $1.50 | 3.00 |
| 1 Engineer | 2.00 |
| 1 Man moving lumber ahead | 1.50 |
| Coal, oil, steam hose and repairs | 2.50 |
| Total | $25.00 |

Twelve lineal feet of trench, 45 ft. deep, were timbered per day at this cost of $25, or at $2.08 per lin. ft., which is practically $\frac{2}{3}$ the cost by hand above given, and in addition the wear of the sheet plank was less than with hand driving.

The following cost of sheeting is for hand work, trench being 12 ft. wide × 35 ft. deep:

| | |
|---|---|
| 2 Timber men on top, at $2 | $4.00 |
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At this cost, 13 lin. ft. of trench were sheeted per day, or at the rate of $1.77 per lin. ft.

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COST WITH ADAMS TRENCH MACHINE.—This machine consisted of a series of wrought-iron, ∩-shaped bents, the lower feet of the ∩ being provided with wheels running on rails laid each side of the trench. These ∩ bents carried two rails, on each side, beneath the top of the bent, and a car ran along these rails; this car was pulled back and forth by cables from a hoisting engine at one end of the trench; and the same engine raised buckets up to the car where they

were gripped. Working in sand the following was the cost in a trench 13 ft. wide × 45 ft. deep:

| | |
|---|---|
| 18 Men loading buckets, at $1.50 ........ | $27.00 |
| 1 Man operating bucket car ............ | 2.00 |
| 1 Foreman ............................ | 3.00 |
| 1 Engine man ........................ | 2.50 |
| 1 Water boy ......................... | .50 |
| Coal, oil, etc. ........................... | 1.00 |
| Total ............................ | $36.00 |

This force excavated 284 buckets of $1^1/_9$ cu. yds. each, or 316 cu. yds., daily at a cost of 11.4 cts. per cu. yd. It is not stated whether this was loose measure in buckets or place measure.

The same gang operating in a trench, 12 ft. wide × 33 ft. deep, averaged 288 buckets a day, at a cost of 12.5 cts. per cu. yd. It is not stated, but it is presumable, that most of the excavated material was dumped directly from the buckets as backfill into the trench where the sewer was completed.

A Moore Hoister and Conveyor, which differed only in having the bucket car travel on top of the bent, instead of below, required one more man handling the buckets, making the daily force account $38. In a trench 12 ft. wide × 35 ft. deep the Moore machine daily averaged 286 buckets of 1 cu. yd. each, at a cost of 13.3 cts. per cu. yd.

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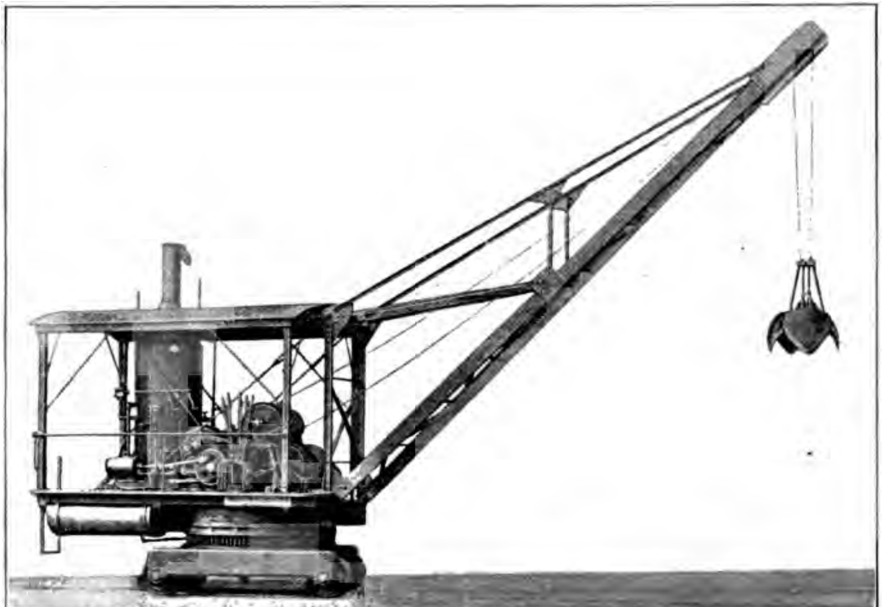

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| 30 Men picking and shoveling | 30.00 |
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| | |
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| 2 Tenders, at $2.00 | 4.00 |
| 4 Plank drivers, at $2.00 | 8.00 |
| 2 Men cutting down planks, at $2.00 | 4.00 |
| 8 Men pulling planks, etc., at $1.75 | 14.00 |
| Total | $55.50 |

This force working in a trench 9 ft. wide × 20 to 30 ft. deep averaged 64 lin. ft. a week in "boiling sand," the pressure of which would break 6 × 8-in. stringers 2½ ft. apart, and 192 ft. a week in gravel and coarse sand, which is equivalent to 70 to 110 cu. yds. a day in the running sand, and 200 cu. yds. in good ground, or at a cost ranging from 80 to 25 cts. cu. yd. A steam pump running at a cost of $10 a day was also required, and about ½ ton of coal was used by the trench machine. The work mentioned was done after the trench machine was set up, and the gang well organized. Another contractor states that it took him two days to dismantle a machine, move it 1,000 ft. and set up again.

This last example of cost is nearer an average than some of those preceding, for it is but natural that, for the most part, manufacturers give examples of lowest cost.

Deep trenching is beset with so many difficulties, such as the handling of unexpected bodies of water, the caving of banks even when well sheeted, and the like, that liberal estimates of cost should always be made. Then $7 to $10 a day should ordinarily be added for rental of the trench machine, for even where owned by the contractor a liberal allowance must be made for wear and tear and interest, since so much of the time the machine is ordinarily idle. The cost of the sheeting plank must be added, also that of pumping. In many localities boulders are likely to be encountered greatly delaying work and adding to the cost.

Accidents to men are frequent—so much so in some soils that accident insurance companies absolutely refuse to insure a sewer contractor's men. Accident insurance is seldom less than 1% of the pay roll, even on safe work, and on sewer work it often runs up to several per cent. An engineer, as well as a contractor, should always ascertain the exact charge for insurance in any given locality, and include it in his estimate of cost.

# CHAPTER XV.

## The Cost of Hydraulic Excavation.

To California gold miners and mining engineers the world is indebted for the development of the cheapest means known for moving earth. Engineers in general are apparently strangers to the great economy of the hydraulic method of excavation, or if not ignorant of its economic merits as applied in California, they hesitate to use the method elsewhere. However, there is nothing mysterious or difficult about the hydraulic method of earth excavation, nor does it always require so great an expenditure for plant as to put it beyond the reach of those contemplating excavations of any considerable size. It is generally assumed that there must be a gravity supply of water, but even this condition is not essential to economic excavation and transportation of earth, as we shall presently see.

At the November, 1901, meeting of the American Institute of Mining Engineers, Mr. William H. Radford, of San Francisco, read a paper entitled "Notes on Hydraulic Mining in Low-Grade Gravel," wherein are contained data valuable to civil and mining engineers alike. A ditch 11 miles long delivered water to the "giant," as the huge nozzle is termed. Two men during the rainy season and one man during the dry season cared for the ditch. Water was purchased for 0.69, or practically 0.7-ct., per miner's inch of 1,728 cu. ft. per 24 hours. During the season from November, 1899, to the last of July, 1900, 655,657 miner's inches washed down, by actual survey, 1,251,399 cu. yds. of gravel, or 1.91 cu. yds. of gravel per miner's inch. From this we see that 906 cu. ft. (= 33½ cu. yds.) of water were required to move each cubic yard of gravel.

The gravel was partly washed from the river-bed to a depth of 1 to 8 ft., until bedrock was reached (7,134 acres of bedrock uncovered), but a large part was washed from the mountain side by attacking a face 50 to 130 ft. in height, averaging 63 ft.

Long cuts or rock ditches were excavated in the slate bedrock into which the gravel was washed when cleaning off the bedrock. The total cost of moving this gravel was only 2½ cts. per cu. yd., itemized as follows:

COST OF HYDRAULIC EXCAVATION.
(1,251,400 cu. yds. gravel.)

| | |
|---|---|
| Care of ditches and reservoir, labor | $2,670.99 |
| Care of ditches and reservoir, supplies | 115.55 |
| Washing (piping) | 2,401.05 |
| Drilling bedrock ditches by hand | 1,050.91 |
| Drilling bedrock ditches by electric drill | 269.62 |
| Timbering rock ditches | 157.39 |
| Electric lights | 598.62 |
| Building sluices and repairs, labor | 1,045.70 |
| Building sluices and repairs, supplies | 35.50 |
| Blacksmithing | 644.02 |
| Cleaning-up gold | 968.79 |
| Moving pipes and "giants" | 898.85 |
| Breaking rocks and clay | 6,124.91 |
| Cutting brush (for piping) | 158.37 |
| General expenses and watching sluices | 3,088.69 |
| Supplies | 3,015.37 |
| Taxes, office and legal expenses, surveying, salaries | 4,267.31 |
| Total | $27,511.64 |

If we deduct such items as pertained only to the recovery of the gold we find that the actual cost was 2 cts. per cu. yd. of gravel moved. This estimate includes no charge for interest and depreciation of plant, which is obviously an item of extreme variation.

The gold recovered by amalgamation was $31,-618.49, leaving a profit of but $4,100 for the season, which is exceptionally low.

The wooden sluices had a 5% grade and were of course water-tight, since any leakage would cause loss of amalgam; but in cases where gold is not to be recovered from the material much cheaper sluices of rough lumber can evidently be used.

Mr. Latham Anderson, in a paper published in the 1901 volume of the Association of Engineer-

ing Societies, gives some abstracts from the United States Geological Survey Report, 1896-97, Part IV., which we can here repeat to advantage in illustrating what has already been done in the way of economic earth excavation.

## Hydraulic Fills on the Northern Pacific R. R.

During 1897, in eight high trestles, 377,000 cu. yds. were moved for about 4.8 cts. cu. yd.

| | | |
|---|---|---|
| Sluicing and building side levees...... | 3.85 | cts. |
| Hay used in levees.................. | .09 | ct. |
| Tools .............................. | .08 | " |
| Lumber and nails.................... | .22 | " |
| Labor building flumes............... | .44 | " |
| Engineering and superintendence..... | .11 | " |
| Total cost per cu. yd........... | 4.79 | cts. |

In the above work water was carried by gravity. In one case pumping was resorted to, and 42,250 cu. yds. were moved for 13½ cts. cu. yd. The plant was inexpensive. One No. 2 "giant" costing $95, with 300 to 1,000 ft. of light sheet-iron pipe costing 27½ cts. per foot, and lumber for sluices, which may be re-used in moving from place to place, constituted the outfit. Five to six men were required to erect and operate the plant.

This work was done in a dense forest, where the ground to be sluiced had to be cleared. In the one case, above referred to, where pumping was necessary, the cost was:

| | cu. yd. | |
|---|---|---|
| Sluicing and building levees.......... | 10.81 | cts. |
| Hay used in side levees.............. | 0.21 | ct. |
| Tools ............................... | 0.14 | " |
| Lumber and rails..................... | 0.12 | " |
| Labor building flume................. | 0.14 | " |
| Coal used in pumping................. | 1.87 | " |
| Engineering and superintendence .... | 0.20 | " |
| Total ........................ | 13.50 | cts. |

In all cases the sluice boxes were paved with square 3-in. blocks laid so that the ends would receive the wear due to the gravel. It was found that grades of 7%, preferably 8%, were best where there was large gravel or rock to be moved. The flumes were made in the most temporary manner of 1¼ in. lumber, the boxes being 16 to 18 ins. square. Hay was used for building up the side levees of the embankment and easily moved baffle-boards to deflect the main current from striking the levees. The waste water was taken off through a waste box. Several gates were provided in the flume so that coarser material might be deposited where the finer is found to be in excess.

The following shows the range of costs:

| Trestle. No. | Cu. yds. | Cts. cost per cu. yd. | Trestle. No. | Cu. yds. | Cts. cost per cu. yd. |
|---|---|---|---|---|---|
| 164 | 18,300 | 8.21 | 182 | 53,600 | 3.80 |
| 165 | 6,200 | 16.58 | 184 | 96,650 | 4.34 |
| 167 | 24,500 | 14.00 | 185 | 800 | 30.24 |
| 170 | 30,800 | 8.75 | 186 | 51,600 | 7.02 |
| 172 | 4.300 | 10.55 | 189 | 158,100 | 5.19 |
| 173 | 9,700 | 6.23 | 190 | 128,800 | 6.11 |
| 178 | 2,100 | 13.25 | 191 | 42,250 | 13.50 |
| 179 | 19,800 | 9.31 | | | |

It will be noted how the cost per cu. yd. decreases as the number of cu. yds. to be moved increases. A railway trestle can thus be filled without interfering with traffic, and when filled there is no settlement of the embankment. Photographs of this work, as well as of similar work on the Canadian Pacific Railway, are given in Schuyler's excellent book on "Reservoirs."

DAM AT TYLER, TEXAS.—This earth dam was built in 1894 by the hydraulic method. The embankment is 32 ft. high, 575 ft. long, and contains 24,000 cu. yds. The water for hydraulicking was pumped through a 6-in pipe from the city pumping station by a Worthington steam pump of 750,000 gallons daily capacity.

In beginning the dam a trench 4 ft. wide was excavated through the surface soil to a depth of

several feet, and was filled with selected clay sluiced in. Then low sand ridges or levees were thrown up at the toes of the proposed dam and carried up as the dam progressed, the clear water being drawn off from time to time.

In loosening the material for the dam a water jet was directed by an ordinary 1½-in. nozzle attached to a 2½-in. hose, and the pressure was 100 lbs. per sq. in.

The washing was carried into the hill on a 3% grade, which soon gave a 10-ft. face, increasing gradually to a 36-ft. face. The jet, of course, was directed at the foot of the face, undermining the material. The cost, including plant, labor, etc., was 4¾ cts. per cu. yd. excavated.

The material was transported in a 13-in. sheet-iron pipe put together stove-pipe fashion, with loose joints. The pipe extended from near the face of the bluff, where the jet was operating, across the center line of the dam. When the end of the dam nearest the bluff reached full height the pipe was raised on a trestle to give it grade for transporting the material to the opposite side. The material transported varied from 18% in clay to 30% in sand. The volume of water pumped, computed on a basis of these percentages, was less than 20,000,000 gallons. The entire cost of this dam was $1,140, which is a marvel of cheapness and illustrates what can be done using the hydraulic method. It should be noted here that dam building should never be attempted with earth sluice ditches in place of pipes, or timber sluice boxes, for the friction of the earth sides causes precipitation of the heavier material, thus separating material into layers of different sizes.

LA MESA DAM, CALIFORNIA.—This dam is described in Schuyler's "Reservoirs" where excellent photographs are given of the work in progress. In this case, no "giants" were used, most of the material being loosened with plows and

carried with scrapers to ground sluices or boxes in which the water ran that carried the material to the dam site. 38,000 cu. yds. were thus handled, some of which was transported 2,200 ft. in the sluices, and 11.5 acres were stripped to a mean depth of 2 ft. to get the material. This shallow cutting made the dam cost three or four times what it otherwise would have cost. The dam was a rock-fill with an earth core washed to place, as described. From the main water supply ditch, laterals were cut so as to divide the area to be excavated into zones 50 to 100 ft. wide by several hundred feet long, leading toward the dam on 6% grade.

Where the grade of ditches was 25% or more, they eroded their own banks, and required no assistance from picks or plows. After these ditches had secured their load of gravel, they delivered to a 24-in. wooden-stave pipe, which carried the material to the dam site. About 2,000 ft. of this wood pipe was used, the first cost of the pipe being 90 cts. a ft. It was made in 12-ft. sections, loosely placed together, and connected by strips of canvas wound around these butt joints, and held with a tarred rope tourniquette The pipes wore rapidly. Sheet-iron or open-wood flumes would be preferable.

During the first 30 days of 24-hrs. each, 700 cu. yds. a day were moved. The solid material was 3.3% of the water, 27 to 45 men, working in 8-hr. shifts, were employed. The cost of loosening was the main item.

HYDRAULIC FILLS ON CANADIAN PACIFIC R. R.—Trestle No. 374, in Frazer Canyon, 231 ft. extreme height, was filled in 1896, with 148,000 cu. yds., at a cost of $5,089, or 7¼ cts. per cu. yd., including cost of plant, explosives used on cemented gravel, labor, etc. Fifty per cent. was cemented gravel, 30% loose gravel and 20% large boulders, which were removed with a derrick. The

plant consisted of 1,450 ft. of sheet steel 15-in. pipe, 1,200 ft. of sluices or flumes, 3 ft. wide × 3 ft. deep; one No. 3 "giant" monitor with 5-in. nozzle, and a large derrick driven by a Pelton water wheel to handle boulders. Piping head was 125 ft. Sluice boxes were laid on a 11% grade for the first 430 ft. and 25% the rest of the distance, 700 ft. The boxes were partly supported on high trestles. The sluices were paved with wood blocks on the light grades, and old railway rails on the heaviest to protect them from abrasion. The entire force of 8 men, were common laborers, except the pipeman and the foreman, working as follows: One man at "giant," one at head of sluice, two along sluice keeping large stones moving, three at outlet of sluice directing stream, and building small retaining barriers of brush or old ties and a foreman who was also a carpenter. The water used was 20 second-feet or 1,000 miner's inches, the duty performed being 1.77 cu. yds. gravel moved per 24-hr.-inch, which is equivalent to about 980 cu. ft. of water per cu. yd. excavated, but it is claimed that if the head had been about 400 to 500 ft. and the gravel all loose, "the duty of the water would have been increased fourfold." Note, however, that amount of water actually used agrees closely with Mr. Radford's placer mining experience above given.

The time of the whole force occupied in making this fill was:

| | 10-hr. days. |
|---|---|
| Sluicing | 95.3 |
| Removing boulders from pit | 50.4 |
| Repairing flume and plant | 13.5 |
| Total | 159.2 |

The total number of yards moved divided by the actual working time when sluicing was in progress gave an average of 738 cu. yds. per 10-hr. day. The cement gravel and boulders, it will be seen,

greatly delayed work. At Chapman's Creek, in 1894, the railway company made a similar fill of 66,000 cu. yds., at 4.34 cts. per cu. yd. for labor, and estimating 20% of the first cost of the plant as chargeable to this job, the total was 7.15 cts. per cu. yd. The actual labor cost of sluicing was only 1.78 cts. per cu. yd.

Mountain Creek trestle was filled in 1897-8 with 400,000 cu. yds. This trestle was 10,086 ft. long, with an extreme height of 154 ft. The fill was carried up on a 1½ to 1 slope. For the first 60 days, of 10 hrs. each, the output of the plant was nearly 1,100 cu. yds. a day, and during that time the cost was:

| | |
|---|---|
| Mattresses | $1,370.79 |
| Labor sluicing | 1,195.96 |
| Maintenance and repairs | 678.90 |
| Superintendence and tools | 385.05 |
| Total, 65,000 cu. yds. at 5.59 cts. | $3,630.70 |

About 2.4 cts. per cu. yd. should be added for the proportionate part of the first cost of plant.

The water was delivered to the "giant" under a head of 160 ft., the nozzle being 5½ ins. The volume was therefore 15¾ second-feet. The ratio of water to gravel was 19 to 1. The sluice boxes were laid on an 8% grade. The water supply was brought two miles in a flume, 4 ft. wide × 2 ft. high, on a grade of 20 ft. to the mile. The entire plant, including roads, camp, stables, flume, 1,200 ft. of pipe line, 600 ft. of sluice boxes, etc., cost $10,038.

THE SAN LEANDRO DAM (CAL.).—This dam, built in 1874-5, contains 542,700 cu. yds., of which 160,000 cu. yds. were deposited by the hydraulic method at a cost of 1/4 to 1/5 the cost of moving earth by carts or scrapers. The water was brought four miles in a ditch, and the sluiced gravel was conveyed in a flume lined with sheet iron, laid on a 4 to 6% grade.

HYDRAULIC MINING.—To the engineer, the most important data relating to hydraulic excavation are results of actual practice showing the number of cubic yards of material excavated by a cubic foot of water. The most complete information that we can find on this subject is given in a paper on "Hydraulic Mining in California," read by Mr. A. J. Bowie, Jr., in 1877, before the American Institute of Mining Engineers. From this paper, which goes into great detail, we have condensed and tabulated the accompanying Table I., which is based upon actual measurements and is reliable.

The total yardage was 2,275,967 cu. yds. gravel moved by 1,533,728 miner's inches (2,159 cu. ft. each), or 1.48 cu. yds. moved per miner's inch, which is equivalent to about 1,440 cu. ft. of water per cu. yd. of gravel; 12,027 oz. of gold worth $231,893 were recovered, the average yield per cu. yd. of gravel being 10.2 cts.; 554 lbs. of quicksilver were lost. The average cost per cu. yd. of gravel moved was:

| | |
|---|---|
| Water | $0.008 |
| Labor | .036 |
| Materials | .010 |
| Office and general expenses | .006 |
| Total | $0.06 |

Two shifts were worked and 1,520 (24-hr.) days were required to move the two and a-quarter million cubic yards, or about 1,500 cu. yds. per 24-hr. day per plant.

TABLE II.—Cost of Hydraulic Excavation; North Bloomfield Claim No. 8.

| Year | 1874-5. | 1875-6. |
|---|---|---|
| Cu. yds. gravel | 1,858,000 | 2,919,700 |
| Height of bank, ft. | 180 | 260 |
| Grade of sluices | 6½ ins. in 16 ft. | 6½ ins. in 16 ft. |
| Labor per cu. yd. | $0.0122 | $0.0140 |
| Powder per cu. yd. | .0032 | .0053 |
| Materials per cu. yd. | .0030 | .0031 |
| General expenses per cu. yd. | .0022 | .0025 |
| Water per cu. yd. | .0077 | .0074 |
| Total per cu. yd. | .0203 | .0323 |
| Cu. yd. of gravel per miner's inch. | 4.80 | 4.17 |
| Cu. ft. water per yd. gravel | 450 | 520 |

TABLE I.—Cost of Mining Five Claims of the La Grange Hydraulic Mining Co. (1874-6, inclusive.)

| | Claims | | | | |
|---|---|---|---|---|---|
| | French Hill. | Light. | Chesnan. | Johnson. | Sicard. |
| Height of bank | 10 to 40 ft. | 24 to 60 ft. | 12 to 62 ft. | 20 to 40 ft. | 20 to 40 ft. |
| Head of water | 50 to 70 ft. | 60 ft. | 50 to 80 ft. | 80 ft. | 90 ft. |
| Nozzles | 4, 5 and 6-in. | 6 and 7-in. | 6 and 7-in. | ...... | ...... |
| Grade of sluices | 4 ins. in 16 ft. | 4 ins. in 16 ft. | 3 to 4", 16 ft. | 3½" in 16 ft. | 3½" in 16 ft. |
| Total cu. yds. of gravel | 679,968 | 683,244 | 284,932 | 196,632 | 155,347 |
| Cu. yds. gravel per miner's inch (2,159 cu. ft.) | 1.08 | 1.82 | 1.87 | 1.76 | 2.89 |
| Cu. ft. of water per cu. yd | 2,000 | 1,186 | 1,577 | 1,227 | 757 |
| Labor per cu. yd. gravel | $0.0420 | $0.0000 | $0.0360 | $0.0200 | $0.0250 |
| Blocks and lumber per cu. yd. gravel | .0042 | .0080 | .0042 | .0029 | .0061 |
| Materials per cu. yd. gravel | .0057 | .0015 | .0062 | .0076 | .0038 |
| Water per cu. yd. gravel | .1040 | .0060 | .0080 | .0060 | .0040 |
| Refining gold per cu. yd. gravel | .0004 | .0003 | .0005 | .0004 | .0007 |
| Total cost per cu. yd. gravel | $0.1563 | $0.038 | $0.055 | $0.037 | $0.039 |

The foregoing indicates about the maximum cost of hydraulic excavation on a large scale, for the banks were not very high, the head of water was low, and the flumes were laid on a very gentle grade—all of which factors increase the consumption of water, as is well shown by comparison with Table II.

We see from Tables I. and II. that the cubic feet of water required to move each cubic yard of gravel may be from 450 to 2,000; and that the cost of labor alone may be 1¼ to 4¼ cts. per cu. yd. It appears that ordinarily about 1,000 cu. ft. of water are required to loosen and move each cubic yard of gravel where banks are, say, 30 ft. high, with about 85-ft. head of water.

As illustrating the expense to which certain companies have gone, the 55 miles of main ditch of the North Bloomfield Co. may be mentioned. This ditch was 5 ft. wide at bottom, 3½ ft. deep, and side slopes were 1½ to 1. The grade was 12 to 16 ft. per mile, and the delivery 3,200 miner's inches, or about 6,900,000 cu. ft. per 24 hrs. Ditches with grades of 20 ft. per mile and delivering 80 cu. ft. per second have been built, and it is to be noted that gagings show about 25% less discharge than open-channel formulas would indicate. Where ravines are crossed, timber flumes 4 ft. wide by 3 ft. deep laid on grades of 30 to 35 ft. per mile are used.

The sluices into which the loose gravel and water are run are made of 1½-in. plank, tongued and grooved about 3 ft. wide × 3 ft. deep; cross-sills, 4 × 6 ins., support the sluice every 4 ft., being mounted on 4 × 6-in. posts. The sluices ordinarily have a 4% grade, and one of the size just given will carry 3,200 miner's inches on a 4% grade; 6 to 8% grades are used where pipe-clay is to be moved. The water must run at least 10 or 12 ins. deep in the sluice, so as to cover boulders of that size and facilitate their moving along. A sudden

break or drop-off in the sluice line can be used to effect the disintegration of cemented gravels.

Banks of cemented gravel often weighing 3,600 lbs. per cu. yd., or 133 lbs. per cu. ft. in place, are broken up by using black powder. If the bank is 50 to 125 ft. high a tunnel is run in about two-thirds the height of the bank, and at the end of the tunnel lateral drifts are run parallel to the face, forming a T. One-half to $\frac{2}{3}$ (25-lb.) keg of powder per 1,000 cu. ft. of gravel, measured in front and above the lateral drift, is the charge placed in the lateral drifts, tamped and fired. As illustrating the accuracy of sampling the yield of gravel determined by test pits and drifts, one example will suffice. Excavations from which 21,600 tons of gravel were taken actually yielded $2.75 per ton in gold, while the estimated yield by sampling was $2.00.

# CHAPTER XVI.

## Cost of Dredging.

While it will be impossible to go very minutely into the cost of dredging, within the limits of a single chapter, still we may record enough facts to give a general idea of dredging economics.

There are four types of dredges in common use: (1) The dipper dredge; (2) the grapple dredge; (3) the bucket elevator dredge; (4) the hydraulic dredge. For harbor dredging the scow carrying the dredging machinery is in some cases provided with pockets large enough to hold several hours' output of the dredge which then steams out to sea and dumps its load. This type of dredge is called a hopper dredge and is used only where the water is so rough that separate scows can not well be fastened alongside.

THE DIPPER DREDGE.—This type is merely a long handled steam shovel mounted upon a scow. The dipper may range in size from 1-3 cu. yd. to 15 cu. yds. The writer at one time operated a small "home-made" dredge having a 1-3 cu. yd. dipper with an 8-HP. hoisting engine. This bantam dredge would average 150 cu. yds. of tough gravel excavated in 10 hours, with a crew of three men, and is described in Appendix C.

On the Chicago Canal, a dredge with 2-cu. yd. dipper averaged 700 cu. yds. place measure per 10-hour day for 6 months, which may be taken as a fair average output. On the Erie Canal deepening where the cut was only 2 ft. a 1-cu. yd. dipper dredge averaged only 300 cu. yds. per 10-hr. day according to the writer's observation. This low output strikingly shows the high cost of "skimming work" as such shallow cuts are.

In Engineering News, Oct. 30, 1902, the following is given relative to the cost of dredging in the Massena Canal, New York State: A dipper dredge, having a 2½ cu. yd. bucket, excavated indurated clay to a depth of 20 ft. below water surface, depositing the material in two scows alongside, each having a drop pocket with a capacity of 140 cu. yds. A tugboat towed the scows a mile to the St. Lawrence River where they were dumped. As towing could not well be done at night only one 10-hr. shift was worked daily. The dredge, tug, and two scows cost $43,000. Interest at 6% is $2,580 per annum, and assuming 6% for depreciation, we have a total of $5,160 to be charged against the average number of days actually marked each year. On a large job of course this may be 200 days or more for a few years, but then there are usually idle years, so we may assume 100 working days, which means $5,160 ÷ 100 = $51.60 daily charge for plant. On short jobs, owners of such a plant usually ask $100 a day rental. The daily wages of the crews of the dredge, tug and scows and the coal bill amounted to $30 per 10-hr. shift, thus making a grand total of more than $80 a day. This dredge averaged 754 cu. yds. per 10-hr. day for 183 days, making the average cost about 4 cts. per cu. yd. for labor and coal, plus 7 cts. per cu. yd. for interest and depreciation. A 1½-cu. yd. dipper dredge also worked one season on the Massena Canal and the cost of dredging with it was about the same. A 6-cu. yd. dipper dredge also showed practically the same cost per cu. yd. These dredges handled clay and boulders that when excavated dry by hand had to be blasted. Neither the orange-peel nor the hydraulic dredges could handle this material.

On the Chicago Canal 5 dipper dredges and 17 scows holding 200 cu. yds. each were worked on one section, the scows being towed away and dumped in Lake Michigan. Hard clay was excavated and the yardage given is for measurement

in place—not in scow. The dredges had 2-cu. yd. dippers, but worked at some disadvantage due to their crowded location. The following was the average output of each dredge per 10-hr. shift:

| | |
|---|---|
| July | 860 cu. yds. |
| August | 780 " " |
| September | 520 " " |
| October | 560 " " |
| November | 460 " " |

The best week's work showed an average per 10-hr. shift of 1,070 cu. yds. for each of four dredges, while one of the dredges averaged 1,530 cu. yds. per 10-hr. shift for that week.

Thus far we have spoken only of place measure in dredging, but very frequently material is measured in scows, and we have seen in Chapter I that we must ordinarily allow for a swelling of 25% for dry loose earth. In allowing for the swelling of dredged earth 35% is frequently assumed as a fair average, but it may obviously be more or less.

The writer kept the following record of dredging with a 1½-cu. yd. dipper dredge working in average earth to a 3-ft. face, which may be called "skimming work." The plant consisted of a dredge, a tug and two scows. The scows were towed half a mile and dumped in deep water. In 20 working days of 10 hrs. each the output was 10,000 cu. yds. scow measure, with the following crew on dredge, tug and scows:

| | |
|---|---|
| 1 Runner | $5.00 |
| 1 Foreman | 3.00 |
| 2 Engineers at $2.50 | 5.00 |
| 2 Firemen at $1.75 | 3.50 |
| 2 Dredgemen at $1.50 | 3.00 |
| 3 Scowmen at $1.50 | 4.50 |
| 11 Men | $24.00 |
| 2 Tons of coal at $3.00 | 6.00 |
| 500 cu. yds. excavated at 6 cts | $30.00 |

Allowance must be made for cost of moving dredge to and from site of work, also for interest, depreciation and insurance.

The dipper dredge is better adapted to all kinds of work, that is it is a better all-around dredge than any of the other three types. It can handle any material that the other types can, and it can handle tough material that the other types cannot unless they are made of enormous size. Boulders and logs do not readily put a dipper dredge "out of commission," even when such a dredge is of small size. Where immense quantities of earth are to be handled by a single dredge, then some one of the other types may prove most economical. But in view of its all-around adaptability the dipper dredge is apt to hold its own for general contracting purposes.

THE GRAPPLE DREDGE.—This type of dredge is also termed a grab bucket dredge, a clamshell dredge, or an orange peel dredge. The bucket, whatever its shape, opens like a hand with two or more "fingers" that penetrate the earth by their weight and then are closed by suitable mechanism so as to grab or grapple a load of earth. This bucket is suspended from the end of a derrick or crane boom, and raised or lowered by means of a chain or wire cable. It is obvious that a dredge of this type is peculiarly adapted to very deep dredging, also to dredging in confined places like the inside of a pier cylinder. It is not adapted to extremely tough material, unless the bucket is made very large and heavy so that it will penetrate by virtue of its great weight. It is a very simple form of dredge however, and one easily extemporized for small jobs in soft material.

A clamshell bucket is in two hinged parts, each having a sharp cutting edge. The weight of the bucket forces these sharp edges into the earth; the edges are then brought together by suitable mechanism. The bucket is then raised and

dumped by opening the two halves. Orange-peel buckets do not differ essentially in operation. They have several segments instead of two. In descending the bucket is usually guided by two long poles, one being fastened to each side of the bucket frame and passing through a sleeve or ring at the end of the boom that supports the bucket.

In Engineering News, Feb. 2, 1899, an Osgood 10-cu. yd. clamshell dredge is described in which no guide poles are used. The bucket alone weighs 15 tons. The crew of this dredge consists of 10 men, and 5 tons of coal are burned in 10 hrs. When working in good material the dredge is capable of delivering a bucket-load every minute.

This dredge, working in water 65 ft. deep, averaged 10 scows loaded with clay in 10 hrs., each scow holding 400 cu. yds. At times a scow would be loaded in 30 mins., each heaped up bucket holding 15 cu. yds. of clay! The record of another clam-shell dredge with the same size bucket was 230 cu. yds. per hour while actually working, but for considerably more than half the time it was "out of commission," due to breakage, time lost in placing anchors, etc.

THE BUCKET ELEVATOR DREDGE.—This type of dredge is also called a bucket ladder dredge, a chain bucket dredge, or an endless bucket dredge. As the name implies an endless chain of buckets, like those on a rock crushing elevator, scoop up the material and elevate it to the top of the ladder where they deliver it into an inclined chute or on to a travelling belt conveyor. The earliest forms of these dredges had chutes inclined 1 in 10 for clay, or 1 in 20 for fine sand, but long chutes became clogged, and on the Panama Canal auxiliary jets of water and travelling scrapers had to be provided to keep the chutes clean. The modern bucket elevator dredge has an endless belt conveyor instead of an inclined chute, which reduces the height to which material must be

raised, and delivers it with certainty of not becoming clogged. The bucket elevator dredge is the type most commonly used in England and Europe, and for canal work should oftener be used in the United States than it is. A small dredge of this type was operated on the deepening of the Champlain Canal, where the cut was only 1 to 2 ft., and it proved far more economic for such light cutting work than a dipper dredge. This indeed is one of the great merits of the bucket elevator dredge, that it can make a shallow cut as cheaply as a deep one. Moreover it leaves a perfectly smooth bottom which other types of dredges do not.

Mr. J. J. Webster read a long paper, in 1887, before the Institute of Civil Engineers (England) in which he gave the following formulas based upon actual tests:

$HP. = 0.04\,T.\sqrt{H}$ for stiff clay; $HP. = 0.026\,T\sqrt{H}$ for soft mud; HP. being the indicated horse power required to excavate and raise T tons per hour to a height of H ft. Where $T = 450$ and $H = 40$, he found $HP. = 98$ in one case, or 1 HP. excavated nearly 4.5 tons per hour.

In the Transactions of the American Society of Mechanical Engineers, 1886-7, Mr. A. W. Robinson, the well-known designer of dredges, gives a paper on bucket elevator dredges in which he says that certain indicator cards showed that 1 HP. would excavate 5 to 9 cu. yds. per hour on a bucket elevator dredge, and 3¾ cu. yds. on a dipper dredge, both working in the same kind of "tolerably yielding material" in water 32 ft. deep. If we assume a total lift of 40 ft., 1 HP. should raise 16½ cu. yds. (3,000 lbs. per cu. yd) of earth per hour, if there were no loss in friction of machinery, no dead weight of buckets and water to lift, and no force consumed in loosening the material.

The bucket elevator dredge is used almost exclusively where gold bearing gravel is excavated. It is claimed that the dipper dredge stirs up the

gravel to such an extent that the gold settles and escapes; and further losses of gold occur through the cracks between the door of the dipper and the sides of the dipper. The writer is not inclined to accept this theory of gold loss, but it is desirable to have a dredge like the bucket elevator that delivers a steady stream of gravel instead of an intermittent stream.

Very little is to be found in print relative to the cost of dredging in America using the bucket ladder dredge.

In Engineering News, Aug. 4, 1892, the output of a Bucyrus bucket-elevator dredge is given. This dredge was used for filling a railway trestle along Lake Pontchartrain, Louisiana. The material was soft and spongy and was taken out in a cut 6 ft. deep by 60 ft. wide. The dredge was at work 16 months filling 34,170 ft. of trestle, with 472,934 cu. yds. measured in cut. The average daily output was 1,180 cu. yds., the best month's output showed an average of 1,770 cu. yds. per day. The day was 10 hrs. long, but due to delays caused by passing trains only 7 hrs. was actually worked. Sunken logs kept the average progress down very considerably. The buckets each held 4 cu. ft. and ran at a speed of 40 ft. per min. The same rubber conveyor belt was still in service at the end of the work. The crew was 6 men, and the average cost of excavation was 3 cts. per cu. yd. Presumably this includes coal, but it is not stated.

THE HYDRAULIC DREDGE.—The essential feature of a hydraulic dredge is the centrifugal pump that raises the earth together with a large amount of water in which the earth is suspended. A rotary cutter or a water jet is used to loosen the material if it is at all compacted, the rotary cutter being far preferable to the water jet in most earths. The discharge from the pump is usually carried through a line of wrought iron pipe, floated on scows, to the place of delivery.

It is obvious that tough clay or gravel containing many large boulders can not be handled with a hydraulic dredge. Sharp sand can be readily pumped, but it cuts the pump shell badly.

For handling comparatively soft material no dredge can compare with a hydraulic dredge in point of economy as the following summary of costs will show. In the Transactions of the American Society of Civil Engineers, 1884, Mr. L. J. Le Conte gives the cost of dredging in Oakland Harbor, Cal., where the average output was 30,000 cu. yds. per month for 8 months; the best month's output was 60,000 cu. yds. in 23 days of 10 hrs. each, the delivery pipe being 1,100 ft. long, 45,000 cu. yds. was excavated in 19 days of 10 hrs. through a pipe 1,600 to 2,000 ft. long, with a lift of 20 ft. above water surface. The dredge had a 6-ft. centrifugal pump, two 16 × 20-in. engines for the pump, and two 12 × 12-in. engines to operate the cutter, etc., and two 100-HP. boilers. A 10 hr. day was worked. The material was mud of clayey nature. The daily cost of operation was:

| | |
|---|---|
| 4 tons of coal at $- | $28.00 |
| 1 gal. oil | .75 |
| 7,000 gals. water | 7.00 |
| 1 captain | 5.00 |
| 2 enginemen | 8.00 |
| 2 firemen | 4.00 |
| 3 deck hands | 6.00 |
| 1 cook | 2.00 |
| 1 water tender | 2.00 |
| Board of 10 men | 5.00 |
| 5% interest on first cost of $50,000 | 10.00 |
| 5% depreciation | 10.00 |
| 8% insurance on $25,000 | 5.55 |
| Repairs | 10.00 |
| | $103.30 |
| 10 men on pipe line on shore | 20.00 |
| 1,200 cu. yds. at 10 cts | $123.30 |

The best month's output cost only 5 cts. per cu. yd.

It will be noted that the price of coal was high, and that laborers received $2 a day. On the contrary the daily allowance for interest and depreciation is altogether too low, as it is assumed that a dredge can be counted upon to work 250 days every year. The proportion of earth to water, by volume, was ordinarily about 15% of earth to 85% of water. A greater percentage of earth, at times 40%, could be delivered, but 15% was the best ratio since it spread out better at the dump. Whenever percentages are spoken of hereafter reference is made to percentage by volume, not by weight.

Mr. J. A. Ackerson presented a paper in July, 1898, to the American Society of Civil Engineers, the paper itself being 100 pages long, followed by a discussion covering 50 pages of the Transactions. This paper describes and illustrates the U. S. government hydraulic dredges built for use on the Mississippi River, and contains the most complete data yet published relative to hydraulic dredging.

The first hydraulic dredge built for work on the Mississippi was a comparatively small affair. It had a Van Wie No. 12 pump with a 14-in. intake and a 12-in. discharge. The main engine was 14 × 18-in., and there were two auxiliary engines each 6 × 8-in. double cylinder. Double pontoons 4 × 50 ft. separated by 4 ft. carried the discharge pipe which was 600 ft. long. This dredge delivered 70 to 100 cu. yds. per hour. It required a crew of 7 men, costing $355 per month. The cost of operating and for current repairs was $2,928 for 90 days, in which time 42,900 cu. yds. of sand was removed at a cost of 6.8 cts. per cu. yd.

The following table is greatly condensed from tables given by Mr. Ackerson, and applies only to three dredges, whereas his tables include six government dredges:

| Name of dredge | "Alpha." | "Beta." | "Gamma" |
|---|---|---|---|
| Cost | $87,000 | $217,000 | $86,000 |
| Capacity, sand per hr | 600 cu. yds. | 2,000 yds. | 800 yds. |
| Draft | 4 ft. 10 ins. | 6 ft. 10 ins. | 4 ft. 3 ins. |
| Main engines | 300 HP. | 2,000 HP. | 500 HP. |
| No. centrifugal pumps | 1 | 2 | 1 |
| Diam. centrifugal pump runner | 6 ft. | 7 ft. | 5 ft. 9 ins. |
| Diam. discharge pipe, ins | 30 ins. | 33 ins. | 34 ins. |
| Delivery head | 20 ft. | 29 ft. | 37 ft. |
| Velocity of discharge, per sec. | 10 ft. | 14 ft. | 10 ft. |
| Agitators or cutters | (6) 2½".† | 6 cutters. | (9) 2½".† |
| Coal used per 24 hours | 500 bush. | 2,088 bush. | 400 bush. |
| Cost of running, per day* | $9.70 | $221.63 | $100.51 |

*Add $37 for cost of steam tender, and $13 for pile sinker, per day of 12 hours.
†Jets.

The capacity of each dredge was ascertained by diverting the material for a short time into a scow where it was measured after drawing off the water. Each of these tests was only 1 to 3 mins. long, and the percentage of sand delivered ranged from 2.4% in the lowest test to 36.4% in the highest. Dredge Gamma showed a remarkable regularity of delivery, the average of 11 tests being 19.1% of sand, weighing 102 lbs. cu. ft. when dry. The efficiency of its pump was 70%. In a test extending over 45 hours the dredge Gamma averaged 1,000 cu. yds. per hour through 1,000 ft. of pipe at a cost of less than 1 ct. per cu. yd. place measure. It is obvious that any such output as this can be made only under the most favorable conditions, and then only for a short time; but it is well to know the lowest possible cost of earth excavation as well as the average.

It is interesting to note in this connection that sand frequently packs solid in the delivery pipe, so that the barges or scows must be large enough to carry such loads of sand in the pipe. Clay in passing through the pipes often rolls into balls several inches in diameter, and these may be used to build up the levees of the receiving basin.

On the Chicago Canal two hydraulic dredges were used on the Willow Springs Division. A description of these dredges is given in Engineering News, Sept. 6, 1894. Each dredge had a 6-ft. centrifugal pump driven by a 250-HP. engine, and the

discharge pipe was 18 ins. diam., made in 33 ft. lengths, coupled with short lengths of rubber hose held by iron clamps. The dredges each worked two 10-hr. shifts daily, and in excavating one and a half million cubic yards of soft loam, the average was 1,732 cu. yds. for each per shift. During one run of 306 working hours the dredge was actually working 230 hrs., and averaged 446 cu. yards per engine hour.

In Engineering News, Oct. 30, 1902, an abstract is given of a paper by Mr. John Bogart who had charge of the construction of the Massena (N. Y.) Canal. Hydraulic dredge No. 1, used on this canal, cost $40,000. It had a 12-in. wrought iron discharge pipe, a rotary cutter and a centrifugal pump driven by a Lidgerwood compound condensing engine of 125-HP. The material was lifted 30 ft. above water level and discharged through 1,200 ft. of pipe. The depth of cut was 22 ft. below water level. The dredge could not operate in indurated clay, but handled soft clay, loam and sand. It worked rain or shine 6 days a week, two shifts of 11 hrs. each for about 8 mos. each year for 3 years, excavating 459,800 cu. yds. The crew was 1 captain, 1 engineman, 1 oiler, 1 fireman, 1 deckhand foreman, and 3 laborers on pipe line at 15 cts. per hr. The wages per shift were $18.

Mr. Bogart assumed 4% interest and 10% depreciation distributed over 209 working days of 22 hrs. each year. Hence for 22 hrs. the cost was:

| | |
|---|---|
| Labor and supervision | $36.00 |
| 9 tons of coal at $3 | 27.00 |
| Oil, waste etc | 5.00 |
| Interest and depreciation | 26.80 |
| Care during winter $209 | 1.00 |
| Total per 22-hr. day | $95.80 |

Very careful observation extending over 194 days showed an average output of 1,125 cu. yds. per day of 22 hrs. or 562 cu. yds. per shift; so that

the cost was 8.5 cts. per cu. yd. Again we call attention to the error of assuming 209 working days as a fair yearly average; but in this case this is balanced somewhat by the liberal estimate of 10% for annual depreciation. The hull of a dredge certainly has a much longer life than 10 yrs., and the same is true of many other expensive parts of the dredge.

Dredge No. 2 cost $60,000 and had an 18-in. discharge pipe. Conditions were the same as for dredge No. 1, except that one more man, a spudman was required per 11-hr. shift. Assuming rates of interest and depreciation as before the cost was:

| | |
|---|---|
| Labor and supervision.................... | $42 |
| 18 tons of coal at $3.................... | 54 |
| Oil, waste, etc............................ | 8 |
| Interest and depreciation.................. | 40 |
| Care during winter........................ | 1 |
| 1,554 cu. yds. at 9.4 cts.................. | $145 |

This dredge worked two seasons and excavated 290,780 cu. yds. It will be noted that it was less efficient than the smaller dredge.

CONTRACT PRICES OF DREDGING.—In Engineering News, Feb. 17, 1898, a very large table is given of the contract prices of dredging for the government from 1895 to 1898.

It is not stated in most cases, whether measurement was in scows or in place, but presumably scow measurement was used in most harbor work for it is extremely difficult to get accurate place measurement in rough water and at great distances from shore. Perhaps the most noticeable feature of the prices given is that price varies inversely as the size of the contract. A small job means a high price per cu. yd., a large job means a low price; thus in New York harbor, 5,000 cu. yds. was contracted for at 30 cts. while 938,000 cu. yds. cost 15 cts. The depth to which dredging is done makes very little if any difference in contract prices.

The following show range of prices:

| | Cu. yds. | Contract price. |
|---|---|---|
| Sacramento, Cal. (hydraulic dredge) | 292,000 | 4¾ cts. |
| Milwaukee (river) | 100,000 | 6 " |
| Keewenaw Point, Mich., scow | 800,000 | 7 " |
| Oakland Harbor, Cal. | 600,000 | 13 " |
| Rockland Harbor, Me. | 470,000 | 14 " |
| New York, harbor, scow | 938,000 | 15 " |
| New York, harbor | 175,000 | 25 " |
| Boston, Mass. | 36,000 | 26 " |
| Niagara River, N. Y. hardpan | 27,000 | 32 " |
| Galveston, Tex., to 17 ft. | 112,000 | 35 " |
| Galveston, Tex., to 12 ft. | 346,000 | 12½ " |
| Portland, Ore. for water pipe | 20,000 | 35 " |
| Illinois and Mississippi Canal | 100,000 | 20 " |
| New York, dredging in crib | 400 | 92 " |
| Green Jacket Shoal, R. I., mud | 37,000 | 15 " |

In estimating contract prices for small jobs the engineer will do well to consult the nearest dredge operators, for if other large jobs are in sight the operators will name very high prices for small jobs, whereas the reverse is true if large prospective jobs are scarce.

# CHAPTER XVII.

## Miscellaneous Cost Data.

This chapter will be found to be a sort of "scrap bag" of cost information.

POST HOLES.—In soft soil a good workman using an 8-in. post hole digger will dig 100 fence post holes in 10 hours, each hole being 2 ft. deep.

In digging holes 24 ins. diam. and 5 ft. deep for telegraph poles, using a crowbar and "spoon" shovel, a man will dig only three holes a day in stiff clay, and seven holes in average earth.

A gang of 4 men digging holes and 6 men raising poles, for a trolley road, averaged 36 poles set per day in ordinary earth.

DREDGING WITH DRAG SCRAPER.—In sinking a grillage upon a pile foundation it was found necessary to cut off the piles below the bed of the river. Before driving the piles a hole was dredged about 25 × 25 ft, × 4 ft. deep, using an ordinary drag scraper hitched to the scow pile driver engine. The water was about 8 ft. deep in this hole when the dredging was finished. The hole was made some 2 ft. deeper than actually needed, to allow for gravel washing in from above. Long wooden handles were spliced onto the drag scraper handles, and a raft was built for the two men who handled the scraper to walk on. It took 4 men, including the engineman, 3½ days to make this excavation. After the piles were driven the 6 men of the scow pile driver crew were engaged 3 days in rigging a circular saw and in cutting off 42 piles, 6 ft. below water. Gravel washing in between saw teeth considerably delayed work by dulling the saw.

POWER SCRAPER.—First on the Chicago Canal and later on the Massena Canal (Eng. News, Aug. 15, 1895, and Dec. 15, 1898), a huge power driven drag scraper was used. The scraper held 3 cu. yds. of loose earth when not heaped and had a cutting edge 7 ft. wide.

It was operated by cables (Fig. 26) running to a 12¼ × 15-in. engine. The towers at Massena were mounted on trucks and were 720 ft. apart. Cable A was used to dump the scraper. The scraper worked there in soft clay, cutting a deep swath; then it was moved over to cut another swath leaving a ridge of earth betwen the two for the purpose of guiding the scraper. Its output in this soft clay was said to be 800 cu. yds. per 10-hr. day, but

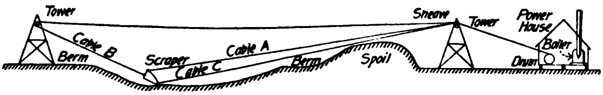



Fig. 26.

the actual records on the Chicago Canal showed only 250 cu. yds. daily output. Mr. Charles Vivian was the designer and contractor in both cases. The scraper did not work satisfactorily in hard material, nor in very wet material, nor in frozen material.

On the Erie Canal deepening small power operated scrapers were used on one contract to drag muck and earth over to a steam shovel which loaded it into cars. The engine was mounted on trucks. A horizontal wooden boom 50 ft. long, with a sheave for the tail rope at the end of the boom, was fastened to the engine truck platform. One or two men attended to loading and dumping the drag scraper which they could readily do as it was small. The hoisting engine thus merely pulled the scraper back and forth.

On the Suwanee Canal (Eng. News, Feb. 20, 1896), a power driven bucket-scraper was used, the Trenton Iron Co., Trenton, N. J., being the man-

ufacturers. Instead of towers, two masts provided with guy lines were used. After the bucket-scraper was loaded by a cable from the engine, another cable lifted it, and it traveled on a trolley conveyor to the dump, very much as buckets travel in the Carson-Lidgerwood cable trench machine. It is said that 200 cu. yds. of earth were moved daily for 6 cts. per cu. yd. with this device.

A COASTING CONVEYOR.—On a small job the writer used a land pile driver and engine for handling caps and other heavy timbers in a way that might also be adapted to moving earth. The

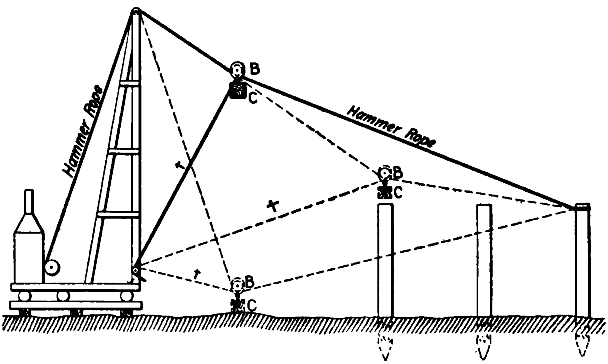



Fig. 27.

hammer rope, as shown in Fig. 27, was fastened to a pile 150 ft. distant, a single sheave block having been arranged so as to travel on the hammer rope. To pick up a cap, C, the hammer-rope was slacked off until in position shown by dotted line. Then the timber C was fastened to the block B. A tag-rope, t, was snubbed around a piece of gas pipe in the hammer leaders, so when the slack was taken out of the hammer rope, the block B and its load were raised as shown. Upon releasing the tag rope, t, the block and its load coasted down the hammer rope to any desirable place, and upon again slacking off the hammer rope the cap was

dropped upon the pile bent desired. This device worked admirably, possessed the merit of simplicity, and might be used for many purposes where the haul is short.

HANDLING BY DERRICKS.—In foundation work it is frequently necessary to use a derrick for handling the earth. Either wooden "skips" or iron buckets are filled with earth by shovelers, and a man-operated, horse-operated, or power-operated derrick is used to lift the buckets out of the way.

Work of this character is always expensive for only a few shovellers can be worked in the pit, and as a consequence the derrick is never worked to its capacity. The following was the cost on one job: A stiff-leg derrick with 35 ft. boom, and three wooden skips (1 × 4 × 4 ft.) constituted the plant. A team with driver was used to raise the skips. The output in soft digging per 10-hr. day was 100 cu. yds.

| | |
|---|---|
| 6 men loading skips at $1.50 ............ | $9.00 |
| 1 man in pit hooking on skips ............ | 1.50 |
| 2 tagmen swinging and dumping ......... | 3.00 |
| 1 team with driver ...................... | 3.50 |
| 1 foreman ................................ | 3.00 |
| 100 cu. yds. at 20 cts. .................. | $20.00 |

This was an excellent record, but the digging was fairly easy. Four skips made a 1½-cu. yd. wagon load, and it took 1½ min. to load, hoist, swing and dump a skip, half of which time was occupied in swinging the derrick boom out and back.

The setting up of a small derrick of this kind will take a crew of men 3 hours or less if the foreman knows what to do, but we have known green foremen to be all day getting the derrick up Where there are trees to anchor to, a guy-derrick is to be preferred, for there are not several tons of stone to be handled as on a stiff-leg derrick which

must be weighted down. Moreover a guy-derrick is quite easily shifted a long distance even while standing. Some contractors set the foot of the mast of a guy-derrick on a framework that rides on skids, and it is then easily dragged over the ground even while upright. A hand winch is never to be used if it can be avoided, for it is too slow a method for moving earth. Wagon boxes of special design are sometimes made to be lifted off the wagon bed with their load of earth and dumped into scows. Wooden skips with two sides only might be loaded by drag scrapers, then lifted by a derrick and dumped directly into wagons or into a bin from which the earth could be drawn off into wagons.

It is not generally known how inefficient a man really is as a lifting machine when working with a shovel. Turning a crank a man can do nearly 2,000,000 ft. lbs. of work per 10-hr. day. Pushing or pulling steadily on a car he will do 1,500,000 ft. lbs. per day. With a good hand pump he will do 1,000,000 ft. lbs. daily. But raising earth with a shovel into a wagon box 5 ft. high, a man will do only 250,000 ft. lbs. work in 10 hours, and in bailing water with a bucket according to Trautwine 200,000 ft. lbs. is a day's work. From the foregoing we see how desirable it is to reduce or do away with the handling of earth by pick and shovel. There are many places, however, where the primitive method will always remain the cheapest; and where time is money to the contractor it often does not pay to wait to instal a mechanical plant. This is well shown in the following case:

WHEELBARROWS AND FLAT CARS.—In Engineering News, Nov. 28, 1885, Mr. Geo. B. Francis describes the excavation of several hundred thousand yards of earth at Portland, Oregon. A steam shovel had been excavating 30,000 cu. yds. of loam and sand per month, but this was not fast enough, so two long platforms, 40 ft. wide × 359

ft. long were built at the foot of the bluff to be excavated, the platforms extending over two lines of railway track. Holes 20 ins. sq. were left in the platform through which wheelbarrows and drag scrapers were dumped into cars below. The face of the bluff was 150 ft. high, 600 Chinese were put to work on one platform loosening, loading and wheeling from this face. Charges of Judson powder were fired in holes at the top of the bluff to heave the earth down where it could be loaded. Drag scrapers and teams were used on the second platform in competition with the Chinese, so that neither gang would consider itself indispensable. With these forces 183,000 cu. yds. were moved in a month. Flat cars held 5.9 to 6.2 cu. yds. each pit measure, and one locomotive handled two trains of cars with a haul of 4,000 ft.

The first month's material shrank 10% from cut to fill but part of it was dumped into water. The shrinkage of the total 416,000 cu. yds. was 3.4% from cut to fill.

PLANK ROADS.—Very often the contractor would be enabled to haul much larger loads in wagons if he were to build plank roads up certain short steep ascents, or up out of the pit. The planks need not be spiked to the stringers. Plank for such roads should be 8 ft. long and 3 ins. thick. Contrary to general opinion cedar makes an excellent plank road, for its surface soon becomes a thin mat of wood fibres and dirt that protect the body of the plank. Either three lines of 4 × 6 in. or two lines of 3 × 12-in. cedar stringers should be bedded in the ground and the plank laid upon them without spiking. In the state of Washington the writer found the cost of building the very best of these plank roads to be as follows: Three skilled laborers bedding three lines of 4 × 6-in. stringers in clay, laying and spiking 3-in. plank, averaged 15,000 ft. B. M. per 10-hr. day. In sand these men averaged 18,000 ft. B. M. per day. They were

hustling, as they received 50 cts. per 1,000 ft. B. M. for laying this road, plank being delivered alongside. Over such a road a team can pull as much as on the very best asphalt pavement. The "trick" about building a good plank road is to bed the stringers, not leaving them on top of the ground. The road then is firm and great loads can be hauled over it, so long as it is kept in good condition.

Since in temporary roads the spiking may be omitted, and as a matter of fact it should be omitted even on permanent roads, we see that the plank may be used over and over again for different jobs; but if the road is worth laying at all it is worth laying well in the first place.

GRADING WAGON ROADS.—In the N. Y. State Engineer's Report for 1899 the following is given: The Hamburg Road, south of Buffalo, is 22 ft. wide, paved with macadam 6 ins. thick, 12 ft. wide. The earth was stiff clay, deep side ditches were dug through comparatively level country. The cost (to the contractor) of grading and trimming one mile involving the excavation of 4,600 cu. yds. was a little more than $1,000 distributed thus:

| | |
|---|---|
| Labor at $1.50 per 10-hr. day ............ | $670 |
| Teams at $3.50 per 10-hr. day ............ | 226 |
| Foreman at $2.50 per 10-hr. day .......... | 97 |
| Water boy at $1.00 per 10-hr. day.. ...... | 17 |
| Total ............................. | $1,010 |

At another section where ditches already existed the resurfacing and forming of earth shoulders to hold the macadam cost $320 per mile.

In the N. Y. State Engineer's Report for 1900 the following is given: River Road, north of Buffalo; the earth was stiff red clay loosened with rooter plows, and hauled 1,000 ft. in patent dump wagons. Labor was paid $1.50 and teams $4.50

for an 8-hr. day. The cost of excavation and trimming was:

| | Per cu. yd. |
|---|---|
| Ploughing | 5.0 cts. |
| Loading | 12.5 " |
| Teaming | 5.5 " |
| Spreading | 5.0 " |
| Foreman, Supt., time-keeper and water boy | 5.0 " |
| Total | 33.0 cts. |

It should be noted that the last item was unusually high.

On the Southport Road, near Elmira, in gravelly earth the grading cost 28 cts. per cu. yd., labor being paid $1.50 and teams $3 per 8-hr. day.

On similar road work near Rochester the writer found the cost to be $1,200 per mile for digging the unnecessarily deep ditches specified (3 ft. deep), forming shoulders for the macadam and sandpapering the slopes, in a compact gravelly soil; this was equivalent to 8 cts. per sq. yd. of roadway from outside of ditchline on one side to outside of ditchline on the opposite side. Labor was paid $1.50 per 10 hrs. and teams $3.50, but there was very little teaming. There were about 3,600 cu. yds. of earth moved per mile. On another level stretch where soft sandy soil was encountered the cost was $600 per mile for grading and trimming, but less earth was moved—not over 3,000 cu. yds. per mile.

FROZEN EARTH.—On the Erie Canal deepening work with wages at $1.50 per 10-hr. day working in the winter time, excavation 1 to 2 ft. deep, to loosen with picks and load with shovels into skips cost 28 cts. per cu. yd. for earth, 45 cts. per cu. yd. for shale rock, and 65 cts. per cu. yd. for hardpan; no powder was used.

In digging trenches where ground is frozen, fires are often built on the ground, but a much more

economical way of thawing the earth is to make a number of wooden boxes, 12 × 24-in. × 16 ft., with open ends; place four of these boxes end to end and wrap gunny sacking or canvas around the joints covering the sacks with earth. Place two lines of these boxes side by side over the site of the trench, and fill the boxes with steam from a boiler. Thawing in this way has been done for 1¾ cts. per sq. ft.

BELT CONVEYORS.—An endless rubber belt can occasionally be used to advantage for conveying earth short distances. Small dry particles can be elevated with such a belt on a slope of 2 to 1, although 2½ to 1 is generally preferable, and with wet gravel and sand from a dredge the writer has had to use a 3 to 1 slope on the Chicago Canal. The Bates Conveyor Co. used a conveyor belt 22 ins. wide travelling on rollers, 5 ft. c. to c., across the canal and up over a movable bridge off which the earth was scraped by fixed scrapers. The slope of ascent was 2½ to 1, and the material was clay excavated with a steam shovel.

As the clay was delivered by the shovel in large lumps it was necessary to break the lumps up in a "granulator," similar to those used in brick manufacture, driven by a 30-HP. engine. Rain and snow caused slipping and clogging of the belt. When not broken down the daily 10-hr. output of this plant was 535 cu. yds. although the best month showed an average of nearly 780 cu. yds. per shift. The force engaged was 35 men, mostly skilled, receiving $2 to $3 a day. In the opinion of the writer, the incline car hoists described in Chapter XII are much to be preferred for such work. A description and drawings of this belt conveyor plant are given in Eng. News, Sept. 20, 1894.

Another belt-conveyor plant was operated on the Chicago Canal by Hoover & Mason. The belt was really an endless bucket conveyor, the buckets being of steel, 4 × 4 ft., hinged on 2-in. axles, pro-

vided with 12-in. wheels. The canal was spanned by a bridge from which the conveyor was hung, and the buckets travelled across the canal resting upon the earth. A gang of plows pulled by cables loosened earth on the slope above the conveyor. this earth rolled down to the foot of the slope where the conveyor buckets scooped it up and carried it to the dump. In July, 1895, the conveyor worked 45 shifts of 10-hrs., and averaged 500 cu. yds. per shift. The best output was 940 cu. yds. in one shift—the designers had counted upon 3,000 cu. yds. per shift after "allowing for delays"! The plant is said to have cost $32,000.

PUDDLE.—Puddle is a mixture of gravel and clay which is wet and rammed or rolled into place. Many engineers use the clay as they would a mortar to fill the voids in the gravel. A few engineers use the gravel merely to insure the crumbling of the sides and roof of any incipient hole in the puddle so as to fill it up.

Fanning gives the following proportions measured loose:

| | Cu. Yd. |
|---|---|
| Coarse gravel | 1.00 |
| Fine gravel | 0.35 |
| Sand | 0.15 |
| Clay | 0.20 |
| Total loose | 1.70 |

This when mixed, he says, will make 1.3 cu. yd. and when thoroughly rammed 1.25 cu. yds.

Another mixture given is

| | | |
|---|---|---|
| Gravel | 1.00 | Cu. Yd. |
| Sand | 0.35 | " " |
| Clay | 0.25 | " " |
| Total | 1.60 | cu. yd. |

This when mixed and spread makes 1.16 cu. yd. and when rammed 1.1 cu. yd.

When clay is not available, very fine sand and a little loam can be used to fill the voids in gravel. Where puddle is used to cover a large area, like the bottom of a reservoir, the gravel is first spread in a layer about 3 ins. thick, the clay is spread over the gravel, and the sand over the clay in their proper proportions. Then an ordinary harrow is dragged by a team back and forth until mixing is complete. Water is next sprinkled over in amount sufficient to cause the mass to knead like stiff dough under a 2-ton sectional roller. Such a puddle is as heavy as concrete and resists abrasion almost as well. With labor at $1.50 and teams at $3.50 the cost of mixing and rolling is 8 cts. per cu. yd. for spreading by hand, 5 cts. for harrowing, 2 cts. for sprinkling and 5 cts. for rolling, making a total of 20 cts. per cu. yd. of puddle, but an exacting engineer can readily make the cost double this amount, bringing it to 40 cts. per cu. yd., which is about what it costs to spread, sprinkle and roll a cu. yd. of macadam.

Where puddle is used in confined places like trenches it must be mixed like concrete by hand and rammed to place at a cost of 30 to 50 cts. per cu. yd. On the Erie Canal, with wages $1.50 for 10 hrs., the contract prices for mixing and laying puddle ranged from 20 to 60 cts. per cu. yd., the average price being 35 cts., and this did not include the materials.

NEW YORK SUBWAY.—The writer has quite a complete record of costs of earth and rock excavation, concrete and steel work, etc., on the Rapid Transit Tunnel in New York city, since the work was begun in 1900. This is a class of work exceedingly expensive, not only on account of the work of supporting of pipes, buildings and car tracks, but because of the comparatively small gangs that must be worked. This not only runs up the cost of superintendance, but due to the great number of foremen employed, many bosses

are exceedingly inefficient. While the laborers receive high wages ($1.50 for 8 hrs.), it will be noted that the foremen are paid altogether too low salaries to secure the best of their class. A good superintendent of railway excavation frequently receives $250 a month, and if he is worth anything, he is worth that. On extensive excavation, cheap foremen mean dear work, as the following illustrates quite clearly:

Case I. Soft earth, ploughed, loaded with shovels into patent dump wagons, hauled half a mile and dumped; 1.9 cu. yds. place measure per wagon load. Excavation 55 ft. wide, in the street, and ultimately 20 ft. deep. Snatch teams, and hoisting engine used to pull loaded wagons out of the pit. Delays in hauling due to street blockades. Numerous pipes and conduits to be supported, necessitating carpenters, plumbers, etc. The following gives the cost for one month's work, including tearing up pavement:

| | | |
|---|---|---|
| Laborers | 1,130 days at $1.50 | $1,695.00 |
| Teams, hauling and plowing | 520 " " 4.50 | 2,340.00 |
| Snatch teams | 30 " " 5.00 | 150.00 |
| Carpenters | 180 " " 2.50 | 450.00 |
| Engineman | 22 " " 2.75 | 60.00 |
| Fireman | 22 " " 2.00 | 44.00 |
| Engineman (night) | 22 " " 2.00 | 44.00 |
| Superintendent | | 100.00 |
| Foremen | 59 days at 3.00 | 177.00 |
| Two time keepers and load checkers | | 135.00 |
| Three watchmen | 78 days at 1.50 | 117.00 |
| Plumbers, caulkers, etc. | | 300.00 |
| Total for 6,400 cu. yds. at 88 cts. | | $5,612.00 |

The foregoing cost was at the beginning of the work, and under what might be regarded as favorable conditions. The following gives the general average of several jobs at a later period, and may be taken as being under, rather than over the actual cost, because all timber work and incidentals are probably not included:

Case II. Conditions same as in Case I., except that excavation, car tracks, etc., required more support.

| | A cu. yd. |
|---|---|
| Labor, excavating and superintendance | $0.50 |
| Teaming | .40 |
| Materials and supplies | .09 |
| Labor on bracing and sheeting | .08 |
| Materials for bracing and sheeting | .07 |
| Labor on bridges and barricades | .01 |
| Materials for bridges and barricades | .01 |
| Taking up pavement | .01 |
| Labor account for pumping and draining | .02 |
| Material account for pumping and draining | .01 |
| Labor on engines | .04 |
| Fuel | .01 |
| Total cost per cu. yd | $1.23 |

A charge of 60 cts. a load, which was equivalent to about 32 cts. per cu. yd. place measure, was paid in addition for removing the excavated material from the water front on scows, thus bringing the grand total cost to $1.55 per cu. yd. for soft earth excavation in New York city! This work was sublet at about $2 per cu. yd. On some sections $2.50 per cu. yd. was paid, and as the contractors have in some cases found that it has cost them $25 per lin. ft. of street to keep the car tracks in shape, and are not yet through with that expense, it will be seen that even at the prices received there was often no profit. It has been said that this work has been poorly managed by contractors, and we can not deny the truth of the charge, but we are confronted with a condition—not a theory—and one that engineers in estimating costs of large works must always take into account.

COST OF RESERVOIR WORK.—In Engineering News, Dec. 12, 1901, Mr. C. M. Saville gives the cost of some work on the Spot Pond Storage Reservoir, near Boston, Mass. Laborers were paid $1.75 and teams $4.50 per 10-hr. day, and worked by the day under a foreman who received 10% of the labor cost for superintending the men and furnishing tools. The following figures show how inefficient the men were under this day-work method.

The shores of the reservoir were stripped of about 40,000 cu. yds. of earth which was $^4/_5$ loom

and $^1/_5$ gravel and hardpan, hauled 1,000 ft.; and the cost was 55½ cts. per cu. yd. Another piece of very compact earth cost 62 cts. a cu. yd., although the haul was only 300 ft.

Clearing and grubbing 5 acres of densely wooded shore, cost $492 per acre, small trees being chopped down, while large ones were undermined, their roots cut off and the tree pulled over by block and tackle, hitched to the tree top, with 20 or 30 men pulling. It cost beside this $100 per acre more to cord up (1,000 cords) the marketable timber, and burn the refuse.

Hauling (800 ft.) and laying several thousand cu. yds. of riprap (18 ins. thick) cost 68 cts. per cu. yd. The labor of seeding 28 acres, including raking and removing roots and stones, cost $43 an acre.

STEAM SHOVEL LOADING WAGONS.—On reservoir embankment work the writer kept records of output of steam shovel loading wagons as follows: The shovel was a Vulcan Giant D special with a nominal 1½ cu. yd. bucket working to a face 8 ft. deep. The "swath" cut was about 27 ft. wide, the material being a clayey glacial drift not requiring blasting. The track rails were cut in 5 ft. lengths, and each forward movement of the shovel was 5 ft.; hence for every 40 cu. yds. excavated the shovel had to be moved forward 5 ft. The crew consisted of a cranesman, a dipperman, a fireman, a pit boss and four pitmen. The shovel loaded directly into patent dump wagons of the Watson make, and one bucketful was considered a fair wagon load. Although some wagon loads were large, others were smaller, making the average nearly 1 cu. yd. measured in cut. The round trip was 2,700 ft. or practically half a mile over nearly level earth roads. When the shovel was working steadily it loaded a bucketful every ½ min., at which rate, if there were no delays waiting for wagons or in moving forward, 1,200 buckets would be loaded in 10 hrs. As a matter of fact 750 to

800 loads were the daily 10 hr. output, the best day being 900 loads, or practically 900 cu. yds. To move the shovel forward ordinarily consumed 4 or 5 min.; hence for every 20 mins. of shovel work in loading 40 wagons, there were 5 mins. added for forward moving, making 960 loads the very best possible theoretical output with this shovel under these conditions, and as above stated this maximum output was nearly reached on the best day. The stalling of a team at the dump would occasionally delay a whole string of teams a few minutes, and other minor causes of delay both of teams and of shovel, reduced this theoretical 960-load output by about 15%, or to about 800 cu. yds. Every fourth day the shovel reached the end of its 400-ft. run and had to back down and start a new "swath." The crew worked overtime to do this.

There were 19 to 20 teams and they made the round trip of half a mile in 13 mins., if not delayed, but with minor delays at shovel, etc., 40 to 42 trips (20 to 21 miles) per team was all that could be expected. Wagons were dumped without stopping the team, and the driver wound up the bottom without leaving his seat and without stopping the horses. Nevertheless it was quite evident, as before stated, that 20 miles a day is about all that can be counted upon over fair earth roads even where there are no delays. The patent dump wagon with its short deep box is especially adapted for loading with a steam shovel.

At the embankment there were 12 men and a foreman, engaged for the most part in picking out cobbles and throwing them over the bank, also doing some spreading of the earth. Four horses and two men leveled the earth with a light reversible Austin leveler or road machine; and after leveling they ran a grooved roller over the material to compact it. Sprinkling was done from a line of 1-in. pipe in which valves were placed every 50 ft., so that one man with a hose readily did the water-

ing. The labor cost of this work per day was as follows:

| | | |
|---|---|---|
| 1 | Cranesman | $4.00 |
| 1 | Dipperman | 3.00 |
| 1 | Fireman | 2.00 |
| 1 | Pit boss | 2.50 |
| 4 | Pitmen at $1.50 | 6.00 |
| 19 | Teams on wagons at $3.50 | 66.50 |
| 2 | Teams on leveler | 7.00 |
| 12 | Men on dump at $1.50 | 18.00 |
| 1 | Man sprinkling | 1.50 |
| 1 | Water boy | .50 |
| 1 | Foreman on dump | 3.00 |
| | Total | $114.00 |

With an output of 800 cu. yds. daily the cost of labor and fuel was 15 cts. per cu. yd. of excavation. To which must be added interest and depreciation of plant, and cost of moving shovel. This is an unusually low cost for reservoir work.

COST BY CABLEWAY AND CARS.—Parallel with a railroad track a trench 14 ft. wide by 18 ft. deep was dug in earth slightly more compact than "average." A Lambert cableway with towers 400 ft. apart was used, and it delivered the buckets to a chute that discharged into railroad cars alongside. The writer's record of cost were as follows:

FORCE.

30 men loading buckets.
1 signalman (signaling engineman).
1 man hooking buckets to cable's trolley.
1 man dumping buckets.
4 men driving sheet plank and bracing.
5 men spreading earth in cars and moving cars.
1 engineman.
1 fireman.
1 water boy.
1 foreman.

46 total.

The output was 260 buckets in 10 hrs., each bucket holding $1^1/_8$ cu. yds. of loose earth which was probably not much more than 1 cu. yd. measured in cut. The wages and coal amounted to $76 a day. Hence, not including the cost of timber sheeting, nor the hauling and unloading of cars, the cost of excavation was about 30 cts. per cu. yd. There was no backfilling. When the bucket was traveling 360 ft. from pit to dump, the following time was required for each round trip:

| | |
|---|---|
| Raising bucket | 15 seconds. |
| Moving bucket 360 ft | 35 " |
| Dumping bucket | 25 " |
| Returning bucket | 35 " |
| Lowering bucket | 15 " |
| Changing buckets | 15 " |
| Total | 140 seconds. |

Almost 5 secs. could be saved on each of these six items if everything went well, but with the ordinary slight delays the above is a fair average for each round trip—that is $2^1/_3$ mins. A cableway may be used to advantage in pulling sheet planking, and one 2 × 10-in. plank buried 16 ft. in the earth can be pulled in 1 min., thus making the cost of timber removal merely nominal. In pulling the plank use a piece of 1 × 3-in. iron bent into a U-shape and with a ring welded to one leg of the U. It clings to the plank even though it is not held by a set screw or the like.

To move one of these cableways takes a gang of 15 men three days if they are "green" at the work, two days if they are used to it. The anchorage for the main cable is made by digging a trench 5 or 6 ft. deep and 16 ft. long, in which a log 16 or 18 ins. in diameter and 15 ft. long is laid, and the cable carried around its centre. A short narrow trench leads off from the main trench so as to give a clear way for the cable to pass to the top of the tower.

The main trench is filled with stones carefully laid over the log, and on top of the ground over the log is built a pile of stones 6 ft. high × 12 × 12 ft. To move all this rock for the anchors, to move the engine, towers, cables, etc., and set up again will seldom cost less than $50, and frequently costs $75, to say nothing of the lost time. If this cost is added on the cost of excavating the earth in a trench 370 ft. long, it will amount to several cents per cu. yd. Thus if the trench is only 6 ft. wide × 9 ft. deep, there will be 740 cu. yds. in 370 ft. of trench, and if it costs $74 to move the cableway, we have 10 cents per cu. yd. of trenching chargeable to the cableway moving, besides the cost of excavation and back fill. For deeper and wider trenches this cost of moving, being distributed over a greater yardage, becomes a comparatively small item. Each case must be treated as a separate problem, in ascertaining the cost.

# CHAPTER XVIII.

## Earth and Earth Structures.

VOIDS AND WEIGHT.—A mass of spheres, all of the same size, packed as closely as possible has 26% voids or inter-spaces; but packed as loosely as possible such a mass has 48% voids. A tumbler full of bird shot has 36% voids. Sand with rounded grains of nearly uniform size has 41% voids; while crushed quartz sand of uniform size has 55% voids. It is evident that where large grains and small grains are mixed the percentage of voids of the mass is decreased, but it is not decreased to the extent that might be expected theoretically. Thus when 1 cu. ft. of coarse gravel, having 40% voids, is mixed with 0.4 cu. ft. of sand, we do not get 1 cu. ft. of gravel and sand mixture as might be expected. In practice, no mixture of clean sand and gravel reduces the voids to much less than 22%.

It is generally safe to assume that pit sand or gravel has 35 to 40% voids when measured loose. Loose sand of uniform size having 45% voids and weighing 85 lbs. per cu. ft., can be compressed to 36% voids and 96 lbs. per cu. ft. by saturating with water and ramming. Gravel, however, will not shrink as much under the rammer. Pebbles of uniform size having 44% voids, weighing 84 lbs. per cu. ft. can be rammed to a mass weighing 92 lbs. and having 39% voids. An artificial mixture of gravel and sand weighing 125 lbs. cu. ft. loose and having 30% voids can be rammed until it has 20% voids and weighs 145 lbs. per cu. ft. Pure solid or massive quartz weighs 165 lbs. per cu. ft., hence if the gravel and sand mixture just mentioned had been of quartz it would have weighed $165 \times 0.8 = 132$ lbs. per cu. ft. instead of 145. We therefore see that the minerals

composing this particular sand and gravel were of basaltic or similar rock origin. Solid basalt or trap weighs 181 lbs. per cu. ft.; hence $181 \times 0.8 = 144.8$ lbs. per cu. ft. where voids are 20%.

Trautwine gives the following:

| | Lbs. per cu. ft. |
|---|---|
| Dry loam, loose | 72—80 |
| " " shaken | 82—92 |
| " " moderately rammed | 90—100 |
| Moist loam loose | 66—76 |
| " " shaken | 75—90 |
| " " moderately rammed | 90—100 |
| Loam, mud | 104—112 |
| " mud, pressed into a box | 110—120 |
| Sand, pure quartz, loose and dry | 90—106 |
| " pure quartz, saturated with water | 118—129 |
| " with its natural moisture and loose | 85—90 |
| Potter's clay, dry and solid | 119 |
| Potter's clay, dry and in lumps | 63 |

The voids in compact clay are given by Fanning as being 8 to 15%, average 12%, the clay weighing 125 lbs. per cu. ft. Clay, however, is composed largely of decomposed feldspar which has a specific gravity about the same as that of quartz, that is feldspar weighs 165 lbs. per cu. ft. solid; hence if there were only 12% voids in clay, it should weigh $165 \times 0.88 = 145.2$ lbs. per cu. ft. We see, therefore, that clay really has a far greater percentage of voids than 12%, but the inter-spaces are so very small that water can not readily penetrate, so the ordinary test to determine the voids of clay by pouring water upon it is evidently deceptive.

NATURAL SLOPE.—The slope that the face of a mass of earth assumes when exposed to the elements for several months is called the natural slope. The angle of repose is the angle or slope that a face of earth makes with the horizontal, when not subjected to the elements.

The angle of repose of various earths is given by Molesworth as follows:

| | | |
|---|---|---|
| Compact earth | 50° | or 1¾ to 1 |
| Clay, well drained | 45° | " 1 " 1 |
| Gravel | 40° | " 1¼ " 1 |
| Dry sand | 38° | " 1¼ " 1 |
| Wet sand | 22° | " 2½ " 1 |
| Vegetable earth (loam) | 28° | " 1¾ " 1 |
| Wet clay | 16° | " 3 " 1 |

Rankine agrees with Molesworth for the most part, but puts the angle of repose of dry sand at 28 to 30° or 1¾ to 1.

Engineers generally make railway and similar embankments with a slope of 1½ horizontal to 1 vertical, 1½ to 1, regardless of the material.

The slopes of cuts are very frequently made 1½ to 1 also, although many engineers specify 1 to 1, and occasionally some one appears who favors ½ to 1. A slope of ½ to 1 will, on a cut 30 ft. deep, slough off in time, growing flatter, but it is argued that in some cases it pays to save excavation at first in this way, and later clean up as the bank crumbles down. In steam shovel cutting it would be the height of folly not to do all the needed excavation at once and be done with it.

Fanning says that gravels, and mixtures of gravel, clay, etc., will stand at 1½ to 1 under ordinary rains; but that upon shores exposed to waves gravel takes a slope of 5 to 1 if unprotected. The writer has observed that on the shores of Lake Erie sand exposed to waves assumes a slope of 10 to 1.

FRICTION.—It is often desirable to know the coefficient of friction of earth upon itself or upon metal or wood. The tangent of the angle of repose will give the coefficient of friction, f, of earth upon itself when subjected to light unit pressures; but the tangent of an angle is found by dividing the perpendicular by the base, hence $f = \frac{1}{1.5} =$ 0.66 for earth having a slope of repose of 1.5 to 1.

The following coefficients, f, will be found useful; they are given by Trautwine:

| | | |
|---|---|---|
| Masonry wall on wet clay | 0.2 | to 0.3 |
| " " " dry earth | 0.5 | to 0.7 |
| " " " sand or gravel | 0.65 | to 0.75 |
| " " " dry wood | 0.6 | |
| " " " wet wood | 0.75 | |
| Iron on dry earth | 0.4 | to 0.5 |

The following data have been taken from Baker's Masonry:

| | Dry | | Wet. | |
|---|---|---|---|---|
| | Beginning motion. | During motion. | Beginning motion. | During motion. |
| Cast-iron, unplaned, on sand and gravel. | .37 | .47 | .36 | .50 |
| Cast-iron, unplaned, on sand............ | .56 | .61 | .47 | .38 |
| Granite, roughly dressed, on sand & gravel | .43 | .54 | .41 | .48 |
| Granite, roughly dressed, on sand..... | .65 | .70 | .47 | .53 |
| Pine, sawed, on sand and gravel........ | .41 | .51 | .41 | .50 |
| Pine, sawed, on sand .................. | .66 | .73 | .58 | .48 |
| Sheet iron with rivets, on gravel and sand | .40 | .49 | .47 | .55 |
| ,, without rivets, on gravel and sand ............................ | .40 | .46 | .33 | .44 |
| Sheet iron with rivets on sand.......... | .73 | .64 | .52 | .50 |
| " without rivets on sand....... | .54 | .63 | .37 | .32 |

It should be stated that the coefficient of friction is constant only within narrow limits of unit pressure, and that the foregoing values of f are for light unit pressures. The writer has discovered by experiment that the coefficient of friction of earth upon earth increases as the unit pressure increases, hence deep down in a bank of earth the coefficient of friction is greater than near the surface. This fact entirely modifies all existing formulas giving the thrust of earth against retaining walls, since all such formulas are based upon the false assumption of a constant coefficient of sliding friction. The writer cannot go into this matter here, but desires to record in proof of this contention that actual experiments have shown that the following formulas express the thrust of earth in pounds per sq. ft. for depths up to 15 ft. with certainty:

(1) $y = 50\sqrt{x}$ For level surface, 1 ft. above bottom.

(2) $y = 60\sqrt{x}$ For inclined, 30°, surface, 1 ft. above bottom.

(3) $y = 90\sqrt{x}$ For level surface, 3 ft. above bottom.

(4) $y = 100\sqrt{x}$ For inclined, 30°, surface, 3 ft. above bottom.

(5) $y = 170 \sqrt{x}$ For mud.
$y$ = horizontal pressure in lbs. per sq. ft.
$x$ = "head" of earth in ft. above point pressed.

The earth weighed 84 lbs. cu. ft. and its angle of repose was 38° 22′. A door 1 ft. square with its center 1 ft. above the bottom of the wall and another similar door with its center 3 ft. above the bottom were provided with a weighing device to measure the pressure, as described in Engineering News, Oct. 19, 1899. From the data so found by Mr. A. A. Steel, the writer has deduced the formulas above given. It will be seen that they are the curves of parabolas. Hence the area of the semi-parabola will give the total horizontal thrust, H, of earth against a wall, whence

(6) $H = \frac{2}{3} x y$

Combing eq. (3) and (6) we have

(7) $H = 60 \sqrt{x^3}$.

Equation (7) gives the total horizontal thrust of a level mass of earth against a wall x ft. high, and errs on the side of safety for as shown by eq. (1) the actual pressure decreases near the bottom of the wall. The application of this force H is not 1/3 x above the bottom as in water pressure, but is 0.4 x above the bottom, for the center of gravity of a parabola is 0.4 x above its base. The writer will at another time give the results of other tests and the mathematical deduction based thereon, showing how the foregoing formulas may be derived in much the same manner that Coulomb and Rankine have derived their erroneous formulas, erroneous because based upon the assumption that the coefficient of earth friction is a constant, which it is not.

SLIPS AND SUBSIDENCES.—In Chapter I. we discussed in detail the shrinkage of earth, and a brief consideration of the cause of slips or land slides will now be given. It is a remarkable fact

that an English author has managed to write quite a large book on this subject of earthwork slips; but after reading the book through with care we marvel even more at the author's ability in so effectually burying a few facts beneath a landslide of words. In a nutshell it may be said that the saturation of an unctuous earth with water is the cause of earth slips in cuts and fills. An inclined seam of soft clay, or of marl, or of quicksand underlying a mass of earth will cause slipping of the mass if a face is exposed and the angle of repose is exceeded.

The jarring of passing trains reduces the coefficient of sliding friction of earth upon earth and is the cause of some slips. High embankments built upon side hills in a clayey country often cause extensive slips of the underlying earth, and settlements of the embankment. Where experience has showed that such slips are to be expected, tile drains may be used to advantage in the site of the proposed embankment. Often there is no way of predicting a slip, and when it begins it is too late to do any draining of the subsoil. The fill has then to be carried up until the slipping stops of its own accord. An engineer is peculiarly helpless under such conditions. He may find upon examination that the real source of trouble lies in the damming back of water by the new embankment, which water by soaking into the subsoil so reduces the coefficient of sliding friction as to cause the slip. In that case the remedy is obviously drainage ditches along the upper toe of the embankment, leading to a culvert. As stated in the forepart of this chapter, increasing the unit pressure upon earth increases its coefficient of sliding friction. This being so we can ascribe movements of the soil beneath an embankment to but one cause—water. It would be more than a waste of words to attempt to outline all possible methods of getting rid of this water, as our esteemed English authority has tried to do. In many cases it is

impossible, with reasonable expense, or even with unreasonable expense, to get rid of the water that saturates and so lubricates the subsoil.

If embankments are to be built upon soft swampy muck, a compression of that muck is inevitable. The engineer should endeavor to secure a uniform distribution of the earth load so as to secure uniform settlement. This uniform loading he should have *during* construction as well as afterward. That is he should build the embankment up in horizontal layers—not by end dumping—if he can. For a concentrated load will simply push the muck out from under the load and not compress it. If it is impracticable to build up in uniform layers, then it may pay to build a log or brush mattress upon which to dump the earth. The writer has read very many accounts of the building of such mattresses written by those who seemed to think that in some way the mattress served to buoy up or float the finished embankment. As a matter of fact these mattresses ordinarily serve but one useful purpose. They secure an even distribution of the earth load during the construction of the embankment, and so prevent the soft muck from being pushed out from beneath the embankment. In very bad cases a close line of sheet piling along each toe of a proposed embankment may be used instead of the mattress, for it must ever be remembered that the lateral escape of the subsoil muck is what is to be prevented if possible.

It is obvious from the preceding discussion that in building an embankment that the engineer should avoid dumping a mass of marl or soft clay in such a way that subsequent water saturation of it will cause a slip. Many marls are wholly unfit to form an embankment, and if a pocket of such marl is encountered in excavation it should be wasted.

Clay, as is well known, shrinks some 5% when throughly sun dried, thus opening cracks or

crevices through which water may gain access to the material below. A sod covering or a foot or so of sand covering over clay that becomes treacherous in this way will protect it from drying out.

EMBANKMENTS.—In the preceding paragraphs we have considered the prevention of slips and subsidences of embankments, and we are thus led to certain other considerations. We have seen why building up a high embankment in uniform layers may sometimes be desirable. Should all embankments be built up in horizontal layers? We are aware that nearly all text-book writers speak as if it were imperative to build in layers—some even advocating making the layers dish-shaped or concave. As a matter of fact very few embankments in this country, except for reservoirs, are built in layers, despite the fact that most specifications call for such construction. Engineers in practice know more than their absurd specifications will lead their descendants to suspect. Railway embankments are for the most part built by dumping from cars traveling on temporary trestles, and the embankments are thus built up from the end and sides—not in horizontal layers. Results extending over 30 years justify this method of filling by end dumping. Once in a long while we read of a case where the engineer has seen fit to use drag scrapers to level off the earth as dumped from cars on a trestle. Mr. J. O. Walker wrote a paper entitled "Notes on Filling a Large Trestle," which appears in the 1902 Transactions of the Engineering Association of the South. This trestle was an old permanent trestle, not a temporary one, and was filled with "sand mixed with red loam." Filling a similar trestle had resulted in small slips that threw the trestle out of line, thus delaying traffic on the railway. For this reason the material as it was dumped from the flat cars was leveled with drag scrapers.

Teams received \$2.75 and negro laborers \$1.10 per 10-hr. day. The cost of this leveling was 2½ cts. per cu. yd., and a very compact embankment was thus secured. It cost about 9 cts. more per cu. yd. to excavate with steam shovel and deliver the material. The writer is indebted to Mr. Walker's kindness for a statement of the wages paid.

This it will be noted was the filling of an old trestle on a railway where traffic could not be delayed, and the added 25% cost for leveling was doubtless justified. Ordinarily leveling would cost more than 2½ cts. per cu. yd. on such work, not only because wages are usually higher, but because a sand loam is very readily spread. We do not believe that the added cost of spreading in layers is ever justified in railway or road construction work. What is more, it is very seldom done even when specified, evasion being easy where engineers are so well satisfied that there is no advantage and much added cost in such work. Specifications, therefore, should be altered so as to omit a requirement that is so repugnant to common sense.

Embankments for reservoirs are almost invariably rolled with grooved rollers. In such cases every precaution must be taken to prevent the slightest subsidence that by opening of crevices might let water through and cause destruction of the reservoir. The material must be spread in layers about 6 ins. thick, drenched with water and well rolled with a grooved roller. Seams of sand or clean gravel are of course to be avoided, but an occasional large pebble need not be scrupulously raked out as we often see done. In reservoir embankments we seek to secure just two things: (1) a solidity that will prevent settlement; (2) and a density that will prevent water percolation. Careful work and careful selection of materials are necessary to secure both, but an engineer need not hypothecate his common sense in the earth bank, as often is done by those who place the letter

above the spirit of the specification. That "all vegetable matter shall be excluded" need not mean the careful picking out of every whisp of grass, as was required on the Corning (N. Y.) dikes. In road and railway embankments, of any height above a few feet, sod and similar material at the bottom of the fill can do no harm.

Embankments on side hills are often illustrated in books where a series of steps cut out of the side hill are shown. Personally we have never had to cut such steps and we have seldom seen them. It very seldom happens that a side hill has a slope steeper than 2 to 1—which is a very steep hill—and steps cut into a hill of less slope are useless. Steps could only be useful upon the assumption that in some mysterious way the coefficient of friction between the natural earth and the earth of the fill is lower than 0.5, that is less than a 2 to 1 slope of repose. Sometimes it may be wise to plow the side hill before putting an embankment upon it; this method has the merit of costing little, and of being just as good as cutting steps—even if neither is of any practical use.

EFFECT OF FREEZING.—Water upon freezing expands with enormous disruptive force if confined, but in earth it is usually not so confined, first because earth is seldom completely saturated with water, second because there are avenues of escape for the water. In his book on "Economics of Road Construction" and in an article on "The Cause of Masonry Disintegration," Engineering News, Oct. 23, 1902, the writer has combatted the theory that freezing is ordinarily a primary source of pavement displacement or of rock rupture. We shall not review here the mathematical discussion nor the facts cited to show that freezing as a source of disintegration is a bug-bear. Whatever the theory, the fact remains that macadam roads without any side ditches, but merely crowned and with shallow gutters on each side, are not heaved or

otherwise injured by freezing of the subsoil. The practical conclusion from this is that deep ditches should never be dug in road work with a view to draining the subsoil to a depth below the frost level, as is now done in New York State and Massachusetts roads. Such ditches are moreover difficult to make and necessitate expensive pick and shovel work.

Gutters adequate for all purposes can be made far cheaper with road machines, leveling scrapers or drag scrapers. Only where it is known that a large volume of water must be carried by the ditches should they be made deep and wide. By using these labor saving tools and by so designing the road cross-section that they can be used, an engineer may readily save several hundred dollars per mile of roadwork. Many an engineer has done so—freezing theories, text-books and "standard road specifications" to the contrary notwithstanding.

# APPENDIX A.

## Rapid Field and Office Survey Work.

In the issues of Engineering News of Sept. 13 and Dec. 13, 1900, the author contributed the two papers that follow.

Regarding the endless tape level rod, designed by the author in 1893, and used for years on work in Washington and New York states, it has been claimed that Prof. J. B. Davis, of the University of Michigan, was the first to invent it. Be that as it may, the author had never seen or heard of such a rod up to the time he designed one, and can find no published description of one prior to that in Engineering News of Sept. 13, 1900. Patents were never taken out on the rod, and as more than two years have elapsed since the first published description, any patent claims that might be hereafter allowed will, of course, be invalid.

The "slope tape" illustrated in Figs. 1 and 2 is not the author's invention; it has been used for many years in connection with ordinary leveling rods.

## The Endless Tape Level-Rod and Its Use.

(A reprint from Eng. News. Sept. 13, 1900.)

A letter in Engineering News of July 19 upon the subject of cross-sectioning is doubtless typical of scores of letters that are received by technical papers each year. The writer in each case imagines that the publication of his formulas will be of great assistance to the field engineer. It is safe to say, however, that the practical man will ignore every formula or method that involves much calculation, or in any way adds to his mental labor.

In order to reduce to a minimum the work of finding the points where slope stakes must be set,

the writer some years ago devised a level rod which, in conjunction with a specially graduated tape, makes the setting of slope stakes entirely automatic; and so greatly facilitates the work that 50% more stakes may be set in a day than by ordinary processes.

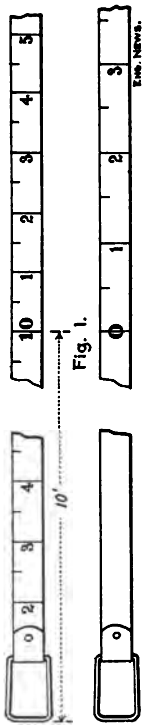
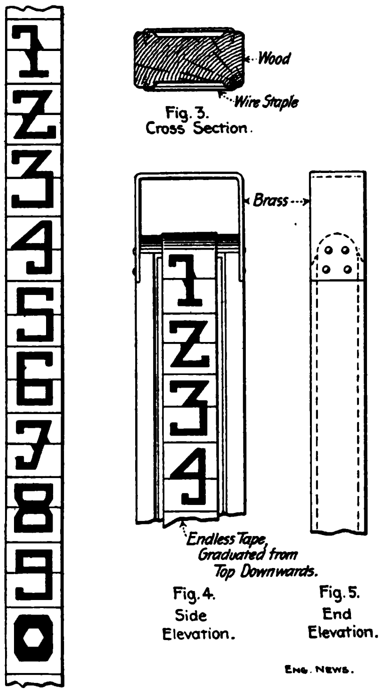



Fig. 1. Fig. 2.

Figs. 1 and 2. Method of Graduating Tape for Cross-Sectioning.

I shall first describe the graduation of the tape and the construction of the rod, afterward indicating the use thereof. Take any ordinary linen tape graduated in feet and tenths, and beginning at the zero end lay off on the tape half the width of the proposed roadbed. If the roadbed is to be 20 ft. wide, lay off 10 ft. on the tape, then turn the tape over and on its blank side and directly opposite the 10-ft. mark paint 0 with India ink. Beginning at this new 0 point make a series of marks $1\frac{1}{2}$ tenths apart, if the side slopes of cuts are to be $1\frac{1}{2}$ to 1; but, if the side slopes are 2 to 1, make the aforesaid graduation 2 tenths apart. Next paint over each mark its proper denomination, beginning at 0 and progressing exactly as any tape is graduated. Fig. 1 shows the front face of the ordinary engineer's linen tape. Fig. 2 shows the rear face of the same tape graduated as just described. The graduations need be carried out only as far as the probable distance of any slope stake from the base line. The rod is somewhat more difficult of construction, but is withal simple and inexpensive. It consists of a strip of white pine 1 × 2 ins. × 10 to 14 ft., dressed so as to leave a bead on each side, as

shown in cross-section, Fig. 3. Passing around the rod lengthwise is a movable endless tape graduated from the top downward; that is, in exactly the opposite direction to the graduations of the common self-reading rod. The ends of the rod are rounded, as shown in the side view, Fig. 5, so that the tape




Figs. 3, 4, 5 and 5. Level-rod for Cross-Sectioning.

will slip readily. The tape should be 1 in. to 2 ins. wide; but, as the writer has been able to find no suitable tape in the market of this width, he has made one by cutting an ordinary 100-ft. linen tape into three pieces, laying two of the pieces side by side, blank face down, and the third piece on top

of the two. The third piece is then sewed onto the two pieces, preferably by a shoemaker, the result being a tape 1¼ ins. in width. Stretch a section of this prepared tape, fastening it with thumb tacks to a table and graduate carefully in feet and tenths, marking with a pencil. Upon this tape stencil the feet and tenth figures, progressing from the top down. Stencils may be cut out of cardboard and the outlines marked on the tape with a pencil, afterward filling it with India ink. The block form of figures shown in Fig. 6 enables one to read to the .01 ft. The graduated tape is stretched around the rod with about the same tension used during the process of graduation and a mark is made where the tape is to be spliced; it is then taken off and a

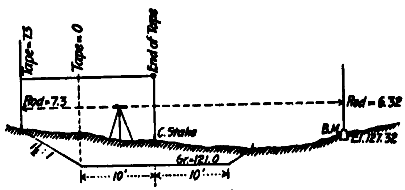



Fig. 7.

**Fig. 7. Sketch Illustrating Method of Using Rod and Tape in Cross-Sectioning.**

soft leather splice sewed on so as to make the tape continuous. To get the tape back on to the rod it is necessary to bend the rod slightly in the form of a bow and slip the tape over the ends. The tape is held in place by small wire staples that span the tape and are driven into the rod at intervals of about two feet. The ends of the rod are protected by U-shaped strips of brass, as shown in Figs. 4 and 5. It would seem that rollers should be provided at the ends of the rod upon which the tape would travel with ease, but the writer has found them unnecessary. It might also seem desirable to provide some sort of a clamp to prevent the slipping of the tape after reading of the rod has been taken, but this likewise is not needed.

The operation of setting slope stakes, using the tape and rod prepared as above described, is as follows: Assuming that slope-stake setting begins at Station 0, and the proposed Grade Elevation is 121.0, while the nearest Bench Mark elevation is 127.32, set up the level at a convenient place, as shown in Fig. 7, hold rod on B. M., and move the endless tape up or down until the rod reads the difference between the B. M. elevation and Grade Elevation, in this case 6.32. Next hold rod on ground at center stake at Station 0, the rod reading will give the center cut direct without further calculation. Next move the rod out to a point where it is estimated the slope stake should be set, and let us assume that the rod reading is 7.3. Measure with the specially prepared tape (shown in Fig. 2) from the center stake to the rod, holding the end of the tape at the stake. If the tape reads 7.3, the spot where the rod stands is exactly the right place for the slope stake; if, however, the tape reads, say 6.6, then move the rod a few tenths farther out and read rod and tape again, repeating the operation until the rod and the tape read exactly alike, and at that point drive the slope stake, marking thereon the rod reading, which will be the cut.

It will be seen that no calculations at all are involved in this method of slope-staking, except the preliminary calculation for the first rod reading, and that errors are practically impossible. Should the grade be + 0.5% from Station 0 onward, it will be necessary to move the tape down 0.5 ft. before taking the rod reading at Station 1, and a like amount at each succeeding station.

When a fill is encountered it becomes necessary to hold the rod upside down, both on B. M. and ground. This can be done without error, since the figures on the rod are equally clear when reversed. If, however, it is feared that errors may be made, another rod should be constructed similar to the one described except that the figures should prog-

ress from the bottom upward; one rod being used for cuts, the other for fills.

The automatic leveling rod is as useful for running a line of profile levels as for cross-sectioning, the operation being as follows:

Hold rod on B. M., whose elevation is, say, 127.32, and set the endless tape so that the last three figures, namely, 7.32, are read on the rod, then wherever the rod is held, the rod reading will give the elevation of the point upon which it is held by prefixing the first two figures of the bench mark, namely 12. In other words, the rod readings give the elevations of the ground or bench mark direct and without calculation. When it is desired to move the level forward, take a rod reading on the turning point, say 1.24; move the level forward, set up, raise or lower the endless tape until the rod again reads 1.24 and proceed as before. It will be observed that the rod automatically adds or subtracts, thus relieving the instrument man of all mental labor; while the notes are kept entirely in one column which is at once the rod reading and ground elevation.

Engineers who are fond of harping upon the great exactness of their leveling will raise the objection that an automatic rod such as described will give results altogether too approximate. With them the writer cannot agree. It is seldom that grading closer than 0.05 to 0.1 ft. is required on any work; and for such purposes a rod read to hundredths on B. M.'s and tenths on the ground is sufficiently exact. Reading rods to thousandths on B. M.'s and hundredths on the ground is one of those absurd time-consuming practices with which the writer has no patience; and it is observable that the engineer that reads to thousandths is the one that oftenest makes mistakes of feet.

The foregoing gives in full the description of the rod and its use as published in "Engineering News." It should be added that a very satisfactory endless tape rod can be readily made by using the

ordinary engineer's wire woven cotton tape, instead of one specially graduated as described. Such a rod can be read to the nearest tenth only, which, however, is close enough for ground readings, and a New York or Philadelphia rod must be used on turning points and bench marks. Any engineer desiring to test the efficacy of an endless tape rod can thus do so at little expense, and with results that are sure to be gratifying.

## Rapid Earth Work Calculation.

(Reprint from Engineering News, Dec. 13, 1902.)

The estimation of yardage forms a large part of the necessary labor of an engineer; and as no class of work is more tedious than the calculation of earth volumes it has been the endeavor of mathematicians to facilitate the work by the use of tables, diagrams and approximate formulas, none of which have met with general favor. Certain college professors have with some reason argued that a good engineer should be satisfied with nothing less than absolute accuracy; some having gone so far as to say that anyone using an excavation formula other than the prismoid formula does so from pure laziness or inability. Professor Johnson, on page 437 of his "Surveying," asserts that there are only two methods that have any claim to accuracy, and gives the preference to the prismoid formula. Practicing engineers, on the contrary, persist in the use of approximate methods, among which the most popular is the one known as the "mean end areas formula," which Johnson condemns. It is well known that this formula receives the sanction of law in New York and other states.

In behalf of the prismoid formula, its extreme accuracy is urged, while in behalf of the mean ends formula its simplicity and rapidity in use are undeniable. In arguing pro and con it is human nature to go to extremes, with the result that the

absurdity of the extreme position taken often acts as a boomerang. The practical man takes cross-sections in rough country so close together that gross errors cannot occur even though using the mean ends formula; and he naturally "pooh-poohs" the theoretical advocate of the prismoid formula who always gives hypothetical illustrations which show a great difference in results between the prismoid and the mean ends formula, simply because they are extreme and hypothetical.

Believing that a compromise might be effected between the advocates of the rough and ready mean ends formula and the advocates of the elegant but complex prismoid formula, the writer undertook an investigation, the results of which follow.

For ease of reference the formulas to be considered will be designated by name and number, thus:

The prismoid formula,

$$V' = \frac{A + 4\,M + a}{6} \times \frac{L}{27}. \qquad (1)$$

The mean ends formula,

$$V = \frac{A + a}{2} \times \frac{L}{27}. \qquad (2)$$

The writer's correction formula,

$$V'' = V - D\,(B - b)\,L. \qquad (3)$$

$V'$ = exact number cubic yards, according to prismoid formula;
$V$ = approximate number cubic yards, according to mean ends formula;
$V''$ = practically exact number cubic yards, according to writer's formula;
$A$ = area in square feet of the larger end cross-section.
$a$ = area in square feet of the smaller end cross-section;
$M$ = area in square feet of the mid-section obtained by averaging dimensions of end cross-sections;
$L$ = distance in feet between end sections;

D = the correction factor to be taken from the writers' Table I.;
B = the larger end area in square feet of a truncated pyramid;
b = the smaller end area in square feet of a truncated pyramid.

It is a fact capable of easy demonstration that the prismoid formula (1), and the mean ends formula (2) give identical results if applied to any five or six-faced figure, provided two of those faces (one of which may be a straight line or edge) are parallel, while the third face is a parallelogram. In other words, these formulas give equal results when applied to wedges, truncated wedges, warped wedges, prisms, and warped prisms, while the results differ only when applied to pyramids or truncated pyramids.

It follows, therefore that the mean ends formula (2) can be applied to any prismoid, and by afterwards applying a minus correction for the pyramids and truncated pyramids, forming elements of that prismoid, we can obtain results agreeing exactly with the prismoid formula (1).

Having reached this conclusion, the next and most difficult step is to deduce a simple correction to be applied to the mean ends formula (2). Tables have been published based upon the mean ends formula and correction columns given in the tables; but the following formula and table the writer believes to be original, and if not, it is undeniably so simple that its merits should be generally known. The reader is cautioned against being dismayed by the apparent complexity of the process used by the writer in deducing the final formula; and any one who does not care to wade through the algebraic processes that follow may without fear of losing the general trend of the deduction, skip the next few lines down to eq. (14).

Deduction of Writer's Correction Formula:

The approximate value in cubic yards of a trun-

cated pyramid, if determined by the mean ends formula, is,

$$V = \frac{B + b}{2} \times \frac{L}{27}. \tag{4}$$

The exact volume, however, as given in Book VII., Prop. 28, Davies' Legendre, is,

$$V' = \frac{1}{3} (B + b + \sqrt{B\ b})\ \frac{L}{27}. \tag{5}$$

The difference between V and V′ as given by these two equations is, therefore,

$$V - V' = \frac{B + b}{2} \times \frac{L}{27} - \frac{1}{3} (B + b + \sqrt{B\ b})\frac{L}{27}. \tag{6}$$

$$V - V' = \left\{\frac{B + b}{6 \times 27} - \frac{1}{27}\ \frac{\sqrt{B\ b}}{3}\right\} L. \tag{7}$$

Having reached this point in his search, the writer began to fear that a simple solution was impossible until it occurred to him to multiply equation (7) by $\frac{B - b}{B - b}$, when he obtained the following result:

$$V - V' =$$

$$\left\{\frac{B + b}{6 \times 27\ (B - b)} - \frac{1}{27} \times \frac{\sqrt{B\, b}}{3\ (B - b)}\right\} (B - b)\ L \tag{8}$$

$$V - V' =$$

$$\left\{\frac{1}{6 \times 27} \left\{1 + \frac{2\, b}{B - b}\right\} - \frac{1}{27} \times \frac{\sqrt{B\, b}}{3 (B - b)}\right\} (B-b)\ L. \tag{9}$$

$$V - V' =$$

$$\left\{\frac{1}{162} - \frac{1}{27} \times \frac{\sqrt{B\, b} - b}{3\ (B - b)}\right\} (B - b)\ L. \tag{10}$$

$$V - V' =$$

$$\left\{ 0.0061728 - \frac{\frac{1}{27}\left[\sqrt{\frac{B}{b}} - 1\right]}{3\left[\frac{B}{b} - 1\right]} \right\} (B - b)\,L. \qquad (11)$$

Let,

$$D = 0.0061728 - \frac{\frac{1}{27}\left[\sqrt{\frac{B}{b}} - 1\right]}{3\left[\frac{B}{b} - 1\right]}. \qquad (12)$$

Then,

$$V - V' = D\,(B - b)\;L. \qquad (13)$$

Whence,

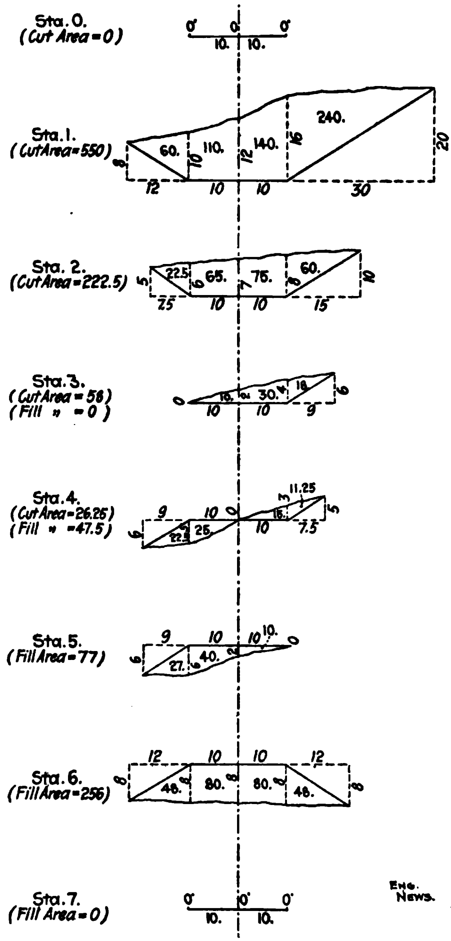
$$V' = V - D\,(B - b)\,L. \qquad (14)$$

Equation (14) is the writer's correction formula.

In Table I. values for D, as determined by equation (12), are given corresponding to different ratios of $\frac{B}{b}$. It will be observed that it requires an increasingly great value of $\frac{B}{b}$ to produce an appreciable variation of D, and it is this fact that makes the writer's correction formula one of great simplicity, since a small table (Table I.) suffices to secure great accuracy, while it is at the same time necessary to obtain only an approximate value of $\frac{B}{b}$, which can be done merely by inspection, ordinarily without even using pencil and paper.

We shall now proceed to illustrate the use of Table I. and the writer's correction formula.

The cross-sections in the accompanying cut are from "The Engineer's Fieldbook," by Cross; and,



Sta. 0.
(Cut Area = 0)
Sta. 1.
(Cut Area = 550)
Sta. 2.
(Cut Area = 222.5)
Sta. 3.
(Cut Area = 58)
(Fill " = 0)
Sta. 4.
(Cut Area = 26.25)
(Fill " = 47.5)
Sta. 5.
(Fill Area = 77)
Sta. 6.
(Fill Area = 256)
Sta. 7.
(Fill Area = 0)
ENG. NEWS.

as the adjacent cross-sections differ far more from one another than is usual in practice, we shall have a severe test of the relative accuracy of the different formulas. The area in square feet of each quadrilateral and triangle is written for convenience on a horizontal line within the individual quadrilateral and triangle; and the volumes as computed by the different formulas are given in Table II.

Beginning with the prismoid between Sta. 0 and Sta. 1, which are 100 ft. apart, we see that it is composed of two pyramids whose bases have an area of 240 and 60 sq. ft., respectively, and of two warped edges with base areas of 140 and 110 sq. ft., respectively. As above stated, the mean ends formula applies with perfect accuracy to these warped edges, so that we need apply our correction formula to the pyramids only. The yardage given by the mean ends formula between Sta. 0 and Sta. 1 is $V = 1{,}018.5$ cu. yds. (Table II.), from which, according to the writer's correction formula, must be deducted $D\ (B - b)\ L$.

In Table I., for $\dfrac{B}{b} = \infty$ (a pyramid), $D = .0062$; therefore, since $L = 100$ ft., $D\ (B - b)\ L = .0062\ (240 - 0)\ 100$, which is to be deducted for the pyramid on the right side, and $.0062 \times (60 - 0)\ 100$ for the pyramid on the left side, making a total deduction of $.0062\ (240 + 60) \times 100 = 186.0$ cu. yds.; therefore, $V'' = V' - D\ (B - b)\ L = 1{,}018.5 - 186.0 = 832.5$ cu. yds.

By the prismoid formula the corresponding volume $V'$ 833.3 (Table II.), a difference of only 0.8 cu. yds, or $^1/_{10}\%$.

The difference would have been 0 had we used the exact value of $D = .0061728$, but the additional labor involved in multiplying by so large a fraction is not warranted by so slight an increase in accuracy.

Between Sta. 1 and Sta. 2 there are two warped truncated wedges, to which no correction need be applied, and two truncated pyramids* with triangular bases to which the correction formula must be applied, as follows: On the right side $\frac{B}{b} = \frac{240}{60} = 4$, corresponding to which, in Table I., $D = .0021$; therefore $D (B - b) L = .0021 (240 - 60) \times 100 = 37.8$ cu. yds., which is the minus correction on the right side, while on the left side $\frac{B}{b} = \frac{60}{22.5} = 3$ approximately.

For $\frac{B}{b} = 3$ we have from Table I., $D = .0017$; therefore, $D (B - b) L = .0017 (60 - 22.5) 100 = 6.8$ cu. yds. Adding the two minus corrections, $37.8 + 6.8 = 44.6$ cu. yds., which is the total correction to be subtracted from the yardage, as given by the mean ends formult, or $V'' = 1,430.6 - 44.6 = 1,386.0$ cu. yds. In like manner the remaining volumes were calculated and tabulated, and it will be seen in Table II. that the results obtained by using the prismoid formula and the writer's correction formula are practically identical, while the error from using the mean ends formula is 9 to 10%.

It must be admitted that even the prismoid formula is not absolutely accurate, being in certain instances extremely erroneous (see Henck's Field-book, page 110), therefore no one can reasonably assert that the writer's correction formula and ta-

*These are not always true pyramids, since their sides prolonged would not meet in a point, or apex; but for all practical purposes they may be assumed as being true pyramids. (Compare (1) and (3) Table II.)

ble give results less near the truth than does the prismoid formula.

TABLE I.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\frac{B}{b}$ = | 1 | 1.2 | 1.6 | 2 | 3 | 4 | 6 | 8 | 10 |
| D = | .0000 | .0003 | .0007 | .0011 | .0017 | .0021 | .0026 | .0029 | .0032 |
| $\frac{B}{b}$ = | 15 | 20 | 30 | 60 | 100 | 500 | 1,000 | 10,000 | ∞ |
| D = | .0034 | .0039 | .0043 | .0048 | .0051 | .0056 | .0058 | .0061 | .0062 |

TABLE II.

| Station. | Cu. yds. cut according to formula— Prismoid (1). | Correction (3). | Mean ends (2). | Mean ends modified. |
|---|---|---|---|---|
| 0 to 1 ............ | 833.3 | 832.5 | 1,018.5 | 845.0 |
| 1 " 2 ............ | 1,388.0 | 1,386.4 | 1,430.6 | 1,399.6 |
| 2 " 3 ............ | 498.1 | 498.3 | 519.4 | 503.6 |
| 3 " 4 ............ | 149.4 | 149.3 | 156.0 | 151.0 |
| 4 " 5 ............ | 32.4 | 32.3 | 48.6 | 36.5 |
| Total ......... | 2,898.5 | 2,898.8 | 3,173.1 | 2,935.7 |
| Error ............... | 0.0% | 0.0% | + 9% | + 1% |

| Station. | Cu. yds. fill according to formula— Prismoid (1). | Correction (3). | Mean ends (2). | Mean ends (2) modified. | |
|---|---|---|---|---|---|
| 3 to 4 ............ | 58.7 | 58.7 | 88.2 | 67.8 | |
| 4 " 5 ............ | 223.3 | 224.0 | 230.4 | 225.5 | |
| 5 " 6 ............ | 585.2 | 586.4 | 616.7 | 593.0 | |
| 6 " 7 ............ | 415.0 | 414.5 | 474.0 | 420.4 | |
| Total ......... | 1,283.2 | 1,283.6 | 1,409.3 | 1,306.7 | + 1.8% |

The advantages of the writer's correction formula and Table I. are these:

1. A saving of time and paper in plotting mid-areas.

2. A saving of time in calculating volumes; for while a study of the foregoing deduction may leave an impression that the process is complex, actual test by use of the table and formula will demonstrate that the time of plotting and calculation required with the writer's method is 30% to 50% less than with the prismoid formula.

3. The mean ends formula may be used for preliminary and monthly estimates, and the corrections applied during leisure hours before the final estimate.

4. Ordinarily no correction at all need be applied where the ground is approximately level.

Notwithstanding the simplicity and accuracy of the writer's correction formula, it is probable that

the mean ends formula will continue to be used by many engineers, especially in states where its use is legalized. This being so, the writer has sought to find some simple rule to guide the engineer in so spacing his cross-sections that results will be within 1 or 2 per cent. of the truth. That such accuracy is ordinarily obtained is undeniable, for no engineer of experience would take sections as far apart as those in Fig. 1, where the variations in the cuts and fills are so great.

The last column of Table II. gives the yardage obtained by the use of the mean ends formula after sections have been interpolated midway between all stations, except in the first and last prismoids, where three cross-sections have been interpolated at + 25, + 50, and + 75. Observe the great reduction in the error from 9% in the fourth column to 1% in the last column.

While it is impossible to mathematically deduce a simple and at the same time invariable rule for the spacing of cross-sections, so that errors exceeding a given per cent. will not occur using the mean ends formula, still it is impossible to offer a rule that will in practice give great accuracy, usually within 1 per cent. of the truth on any section of a railway survey 500 ft. or more in length.

Not the least of the advantages of the mean ends formula is that tables already exist greatly facilitating the estimation of quantities in three-level section work, and using the following rule the engineer may feel assured that his results will be as close to the truth as can reasonably be required.

RULE.—Take cross-sections so close together that no cut or fill shall exceed by more than 50% the corresponding cut or fill in the previous cross-section; except that where the previous fill is 0 the next cut or fill must be 2 ft. or less.

# APPENDIX B.

## Overhaul Calculation.

In railroad excavation it has been the custom to specify a limit of haul within which the contractor received a given price per cubic yard,* as 20 cts. per cu. yd., but beyond which limit he received an additional price, as 1 ct. per cu. yd. for each 100 ft. of overhaul. This limit is termed the "free haul" limit and was usually fixed at 500 ft., or in some cases at 1,000 ft.

Due to the work involved in figuring this overhaul, and due to trouble arising from disputes over interpretation of specifications relating thereto, the overhaul clause has been very generally dropped from specifications. This we believe to be a mistaken policy in most cases. There are many classes of work wherein an overhaul clause, however, is of no particular use; as (1) in heavy cuts where steam shovels and cars are used; the length of haul there making little or no difference in cost; (2) in reservoir work where hauls are ordinarily very short; (3) in street excavations where the hauls are generally very long, the contractor selling the earth for filling lots; (4) in levee or dike work where scrapers are almost entirely used for the short and nearly uniform hauls of such work; and (5) to a less degree in wagon road work where the ditches make the fills, and few long hauls occur.

Wherever there is very slight probability of changing the profile of proposed work after the letting of the contract, the engineer can usually save himself much work by simply giving all data of yardage and haul on the profile. In such a case

*Earth is ordinarily paid for at a given rate per cubic yard measured in "cut" or in "borrow pit," and is not paid for again in the "fill" or embankment except where specific agreement is made to pay for earth measured in fill also, as is sometimes done when the haul exceeds a certain limit.

no overhaul clause is needed, unless it be to guide small contractors who cannot employ an engineer to estimate for them, for the profile shows all the factors needed in making a close estimate.

In extensive railroad work, for example, it is very probable that many changes of line, and consequently of profile, will be made after work has been let and actually started. A conscientious engineer is almost certain to find betterments possible after work begins, hence he should have some clause in his specifications under which he can equitably adjust the price that the contractor should receive in case of changed alinement with resultant change of haul. No clause serves so well for this purpose as an overhaul clause.

There is, however, one precaution which the engineer should take, that is to figure out before the letting of a contract what the total overhaul is to be and to insert it in the bidding sheet, as 40,000 cu. yds., 100 ft. overhaul; otherwise the contractor will bid excessively high (for example, 2 or 3 cts. per cu. yd. per 100 ft. of overhaul) knowing that the engineer has ordinarily no means of determining, at the time of letting, what this item may amount to. With an overhaul price, the engineer can evidently change the alinement and haul without overpaying or underpaying the contractor for his work, and without having claims for "extras" filed.

In railroad work, where the cuts are generally made to balance the fills, earth is often moved with drag or wheel-scrapers, one-horse carts, two-horse wagons, or with small dump cars on rails. Wheel-scrapers are ordinarily considered cheaper than carts up to hauls of 500 ft.; hence contractors accustomed to bidding with the purpose of using wheelers largely, felt the necessity of having some clause in specifications that would enable them to tell to what extent wagons or carts would be used on any given job. Engineers very justly met this desire by the insertion of an overhaul clause. Had

they not inserted some such clause protecting the contractor, the result would have been either a refusal to bid at all on the part of reputable contractors, or an unduly high price if they did bid. It may sound strange in these days of fierce competition and often of "cut-throat prices," to speak as if contractors ever had a voice in the matter of specifications, yet exactly such a state of affairs has at times existed. For example, in one locality the contractors held a meeting at which they voted not to bid upon any work where the specifications did not give a double price for all earth carried past any opening in the road—that is, any place where a culvert or bridge was to be built. The specifications had to be drawn to meet this requirement.

Unless the wording of the overhaul clause is very clear, controversies that may lead to law suits are apt to arise.

Thus in Fig. 1 at Sta. 504, the fill passes into cut. Shall the contractor be allowed to move the cut between Stas. 503 and 504 to the fill between 504 and 505; or shall he be made to haul it the full 500 ft. of "free haul?" There are engineers unfair enough and unwise enough to take the latter stand, acting under some such general clause in the specification as this: "The engineer shall have full power to direct the method and manner of doing all work, not inconsistent with limitations prescribed in these specifications." As a matter of fact were a law suit to follow any such unjust ruling, there can be no doubt that the court would hold that the contractor should be permitted to move the earth as is customary in such work. This being so, it could easily be shown that, ordinarily, drag scrapers are used to move earth for the first one or two hundred feet, the ordinary method of attacking the toe of such a cut being with "drags," later using wheelers as the haul increases, finally using carts, or cars.

We see, therefore, that the contractor ordinarily hauls the earth just as short a distance as he possi-

bly can before dumping it in the fill, and it is but just and right that he be permitted to do so.

There is a method of figuring overhaul that is sometimes advocated (see letter to Editor Engineering News, Mar. 14, 1891, signed "W. R. H.") wherein the center of mass of the whole cut and the center of mass of the corresponding fill are ascertained; then having found the distance apart of these centers of mass the free haul of say 500 ft. is subtracted. This difference is called the overhaul. Obviously this method gives a greater average overhaul than where the common method about to be described is used, and unless clearly specified in the overhaul clause this method should not be used. In Engineering News, of issue just referred to, there is described and illustrated a method of estimating overhaul which is simple, legal, and as exact as can be desired in practice.

The method is described in a letter to the Editor of Engineering News as follows in full:

Sir: In your issue of Jan. 31, a method of estimating overhaul by a profile of quantities, by S. B. Fisher, is published. I have used a method somewhat similar to that, which is illustrated in the accompanying diagram (Fig. 1). This method consists in plotting the quantities in the cuts and fills on ordinary profile paper, and preferably on the same paper on which the ordinary profile is plotted, using the same horizontal scale, and placing the stations for the quantity profile directly above or below those on the ordinary profile, as in Fig. 1. These quantities are final quantities calculated from the construction cross-section notes. Each cut and fill is plotted separately, cutting in red (= heavy solid lines in Fig. 1), and fills in blue (= heavy dotted lines in Fig. 1.); the origins or zero points being at the stations or plusses where the cut changes from cut to fill occur (= grade points).

The total quantity of cut or fill from a grade point up to a given station is plotted opposite that given station, so that in the curve of quantities thus

made, an ordinate at any station represents the total quantity in the cut or fill the grade point (= 0.0 cut) up to that station.

By plotting backward (from the last grade point toward the first grade point of a cut) in the same manner we obtain two curves symmetrical about a

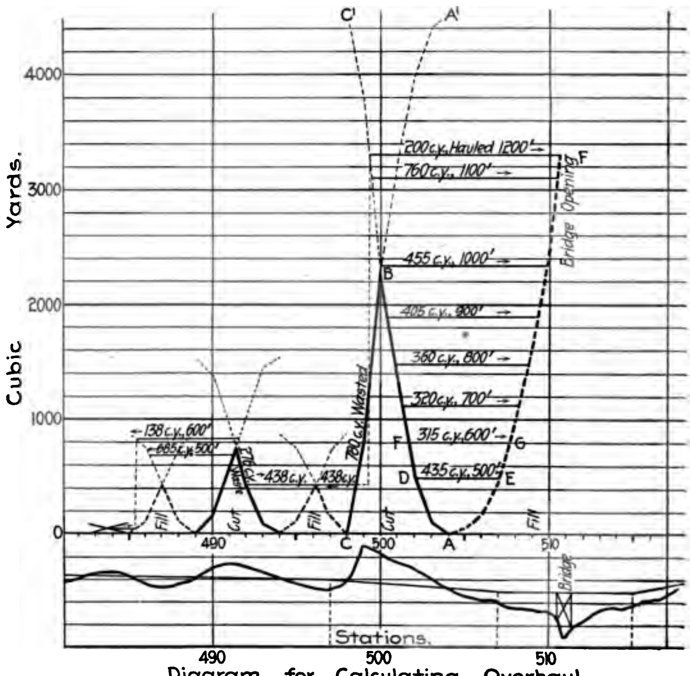



FIG. 1.

horizontal line through their point of intersection, and which intersect in the center of gravity (strictly speaking, center of mass) of each cut and fill.

The method of using this profile of quantities can be best understood by referring to Fig. 1. The cut from Sta. 499 + 30 to Sta. 504 will be hauled into the fill from Sta. 504 to the bridge opening at

Sta. 510 + 75. A, B, C′ and A′, B, C are the quantity curves for this cutting plotted from the grade points in opposite directions. They intersect at B, at Sta. 500, which is therefore the center of gravity of the cutting. A, E, G, F is the quantity curve for the fill. It is plotted one way only, because this fill can be made by hauling one way only, on account of the bridge opening. Supposing that earth is paid for at 16 cts. per cu. yd. up to 500 ft. of haul with an addition of 1 ct. per cu. yd. for each additional 100 ft. of haul: First, find with a scale or pair of compasses, the two points; one on the curve A B C′, and the other on A E G F, which are exactly 500 ft. apart on a horizontal line, and draw a line between them, the line D E. The points D and E represent the stations between which the extreme haul reaches 500 ft. and the ordinate at D (or at E which is the same in length) represents the number of cubic yards cut between the grade point A and the point D, all of which is within the 500 ft. limit. Now find two points on these curves which are 600 ft. apart on a horizontal line, the points F and G. These mark the limits of the 500-ft. haul, and the vertical distance between D and F gives the quantity of earth hauled 600 ft. In the same way the quantity of 700, 800, 900 ft., etc., can be determined, and the stations which mark the limits of these different lengths of haul are found.

Having thus disposed of that part of the cutting from Sta. 499 + 30 to Sta. 504, we turn to the curve plotted backward from the grade point at Sta. 498, and find that by hauling backward from 498 + 50 to 496 + 20 (the center of gravity) we can make just half the fill at Sta. 496; the total quantity hauled being 438 cu. yds., and the maximum distance 230 ft. The balance of the cut from 498 + 50 to 499 + 30, amounting to 780 cu. yds., must be wasted.

It will be readily seen from a study of this method that an engineer can tell in advance where to direct the contractors to borrow and where to waste, and can determine the most advantageous

method of hauling out his cuts as soon as he gets his work cross-sectioned and his quantities calculated.

Of course, if rock is struck in unexpected places, and the quantities are thereby changed, it will be necessary to change the curves, and for this reason it is better not to ink in the quantity profile until the work is finished.

I am indebted to R. P. Bruer, C. E., of the C. P R. R., for this method of calculating overhaul.

T. S. RUSSELL.

Grant, Va.

It should be observed that earth ordinarily shrinks on being packed into a fill under the blows of horses' hoofs, etc., so that each 100 cu. yds. of cut make about 90 cu. yds. of fill. This factor is not mentioned by Mr. Russell, but should be considered by the engineer, if it is desired to get a very close estimate of overhaul.

The next method of estimating overhaul is essentially like the preceding one, although not as easily understood at first reading. It appeared in Engineering News, Jan. 31, 1891, as an article entitled "Estimating Overhaul in Earthwork by Means of the Profile of Quantities," by S. B. Fisher, chief engineer of the Minneapolis, St. Paul & Sault Ste. Marie Ry.

The article follows in full:

No facile, practical and accurate method of calculating the overhaul of earth work is as yet in common use. The problem itself, consisting of finding the relations between the centers of gravity of known volumes in known positions may be, from the mathematician's point of view, a comparatively simple one; but such a lack of readiness to solve it has the engineer shown that many a contract has been executed with the privilege of wasting and borrowing at the end of the haul. This practice

results at times in waste of energy by the contractor, and still oftener in the waste of money to the other party to the contract. By the system of wasting and borrowing, material is paid for at the full price of excavation beyond the haul, but with the judicious use of overhaul, in many cases the material may be hauled half a mile before its price is doubled. When, from the increase of the traffic of a railroad, for example, it becomes necessary to grade for a second track, and in so doing to remove material wasted on the margin of a cut into an adjoining borrow pit along the neighboring fill, where it ought to have been deposited in the first place, it neither increases the respect of the later engineers for the predecessors, nor is it a credit to the profession.

Overhaul as commonly worked out is done in an approximate manner with the ordinary profile and the volumes in excavation and embankment. It takes longer to work it out with the "Profile of Quantities," of which a short example is engraved, but it is done completely and accurately.

The method of the profile of quantities was originated by Bruckner, a Bavarian engineer. It was presented by Cuhlman in his "Graphical Statistics" in 1868, and translated from that by F. Reineker, then (1871-3) Principal Assistant Engineer of the Pennsylvania Co., at Pittsburg, Pa., for the use of his department. This translation was procured there by the writer, and the method adapted to American practice in a great variety of railway work, and is here given with an example of work as actually executed.

The subject is presented, for convenience and clearness, in three steps:

1st. The Compilation of the Data. 2d. The Plotting of the Profile. 3d. The Taking off of the Results.

1. The Compilation of the Data.—The paper containing the data is ruled in five vertical columns, as in the following sample table:

| Station. | Increments. + | Increments. — | Ordinates. + | Ordinates. — | Station. | Increments. + | Increments. — | Ordinates. + | Ordinates. — |
|---|---|---|---|---|---|---|---|---|---|
| 213 + 34.. | ... | ... | ... | ..... | 240.... | 224 | ... | ... | 6,155 |
| 214....... | ... | 370 | ... | 370 | 241.... | 200 | ... | ... | 5,955 |
| 215....... | ... | 843 | ... | 1,213 | 242.... | 180 | ... | ... | 5,770 |
| 216....... | ... | 779 | ... | 1,991 | 243.... | 185 | ... | ... | 5,585 |
| 217....... | ... | 724 | ... | 2,715 | 244.... | 156 | ... | ... | 5,429 |
| 218....... | ... | 902 | ... | 3,617 | 245.... | 102 | ... | ... | 5,327 |
| 219....... | ... | 570 | ... | 4,187 | 246.... | 59 | ... | ... | 5,258 |
| 220....... | ... | 391 | ... | 4,578 | 247.... | ... | 14 | ... | 5,272 |
| 221....... | ... | 457 | ... | 5,035 | 248.... | ... | 70 | ... | 5,342 |
| 222....... | ... | 535 | ... | 5,570 | 249.... | ... | 83 | ... | 5,425 |
| 223....... | ... | 678 | ... | 6,248 | 250.... | ... | 78 | ... | 5,503 |
| 224....... | ... | 723 | ... | 6,973 | 251.... | ... | 65 | ... | 5,568 |
| 225....... | ... | 344 | ... | 7,317 | 252.... | ... | 70 | ... | 5,638 |
| 226....... | ... | 193 | ... | 7,510 | 253.... | ... | 124 | ... | 5,762 |
| 227....... | ... | 156 | ... | 7,666 | 254.... | ... | 181 | ... | 5,943 |
| 228....... | ... | 244 | ... | 7,910 | 255.... | ... | 189 | ... | 6,132 |
| 229....... | ... | 221 | ... | 8,131 | 256.... | ... | 85 | ... | 6,217 |
| 230....... | ... | 356 | ... | 8,487 | 257.... | 55 | ... | ... | 6,052 |
| 231....... | ... | 317 | ... | 8,804 | 258.... | 156 | ... | ... | 5,896 |
| 232....... | ... | 83 | ... | 8,887 | 259.... | 102 | ... | ... | 5.794 |
| 233....... | 161 | ... | ... | 8,726 | 260.... | 146 | ... | ... | 5,658 |
| 234....... | 328 | ... | ... | 8,398 | 261.... | 206 | ... | ... | 5,452 |
| 235....... | 464 | ... | ... | 7,934 | 262.... | 237 | ... | ... | 5,215 |
| 236....... | 493 | ... | ... | 7,441 | 263.... | 250 | ... | ... | 4,965 |
| 237....... | 411 | ... | ... | 7,030 | 264.... | 274 | ... | ... | 4,691 |
| 238....... | 367 | ... | ... | 6,663 | 265.... | 47 | ... | ... | 4,644 |
| 239....... | 284 | ... | ... | 6,379 | 266.... | ... | 6 | ... | 4,650 |

The first column contains the station numbers. In practice the elemental volume is the total excavation or embankment in a full station, whether the station distance is 100 ft., 66 ft., or a number of meters. Plusses are not used, excepting at an occasional beginning or end of a subsection, although the system is flexible enough to apply to any regular or irregular subdivision of these elemental volumes.

In columns 2 and 3 are now entered the total increments or volumes of earth work in excavation or embankment in successive stations. When excavation and embankment both occur within the limit of the same station the net amount only need be entered. If there is a special price for casting within the station another column may be introduced for it. Excavation is considered plus and embankment minus. The latter may be entered in red ink.

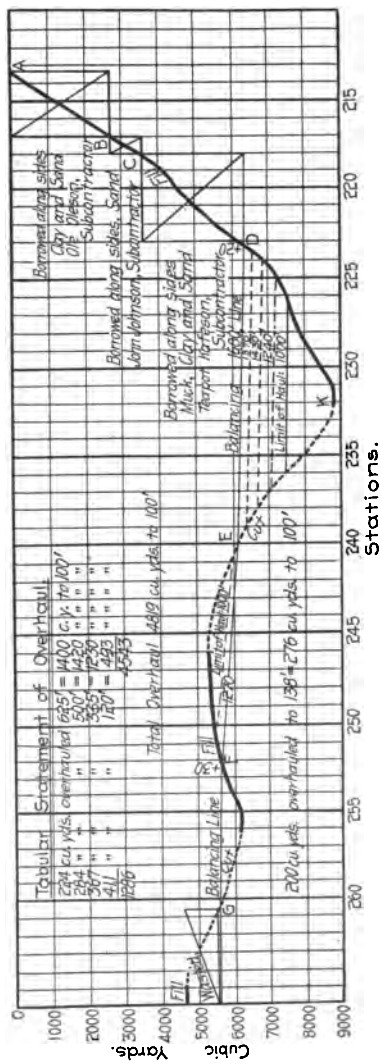
Columns 4 and 5 are now filled up by algebraic addition of columns 2 and 3. The ordinate at any point of the "Profile of Quantities" is equal to the

algebraic sum of the volumes as far as to that point, and should be verified by use of this principle, at convenient points, as the summation proceeds.

2. The Plotting of the Profile.—The horizontal part of the plotting is the same as used in the ordinary profile, and it may be made on the same sheet of paper; but for the vertical part, instead of elevations being referred to a datum plane, at or below the lower edge of the profile paper, we have an initial line or axis of abscissas, located somewhere on the profile, from which the ordinates are measured above for plus and below for minus. Connecting the ends of these ordinates, we have a broken line, which in mathematical language may be called a curve, resembling somewhat an ordinary profile, but wholly different therefrom, composed of the elements between the successive stations.

If the increment, by the use of which any ordinate is formed from the previous one, is positive, this increment of the curve will incline upward, will indicate excavation and be shown by a dotted or blue line. If the increment is negative the element of the curve will incline downward, will indicate embankment and be shown in red or by a solid line. So that excavation on the profile of quantities is always shown by an ascending dotted or blue line, and embankment by a descending solid or red line.

We now consider the balancing line. Some points of this line are always fixed by the patent conditions of the work, and occasionally all points are so fixed, but very often some points on it are indeterminate at first, so that each section is very likely to be a little problem by itself. The functions of the balancing line will most clearly be seen by referring to the engraved sample profile, Fig. 2. We have here the first point of it, A, the beginning of the section; B, the end of Ole Oleson's job; C, the end of John Johnson's job; D, the end of Tea-




Profile of Quantities.

FIG. 2.

pot Kofeeson's job; E, at station 240, the dividing point between backward and forward hauls in the cut; F, station 252 + 30; J, junction point of forward and backward hauls in the fill; G, the point where waste commences in the second cut, and H, the end of the section.

The Taking Off of the Results.—From A to D there is no overhaul, but the nature of the material and any other items can be conveniently recorded there. The fill between D and K, is made from the cut between K and E. We first fix the position of the limit of haul (1,000 ft.) which here comes between stations 226 and 236, and then draw the intervening lines of overhaul to each point of flexture of blue and red lines. We now read the elements of the cut between these lines of haul, from the profile, or if we desire great accuracy, from the data prepared for plotting the profile and tabulate them. Each of these elements multiplied by its respective distance overhauled will give equivalent quantities overhauled to one station; as for example,

$$224 \text{ cu. yds} \times \frac{1680 + 1570}{2} 1000 = 224 \times 6.25 = 1390$$

The sum of these partial products will give the total overhaul for the cut. The tabulation should always be verified, by seeing that the sum of the elements of the blue or red curve, as the case is, is equal to the difference between the extreme ordinates.

If E to K is rock or D to K is a sink hole, the line E D will be inclined, and should be prolonged to an intersection with the horizontal through K. This intersection then becomes a pole, through which the lines of haul are drawn. The method is so flexible it can be applied to anything which can be executed in earth work, and in addition gives a record of what has been done. It is also used to make the preliminary distribution of material before the work is begun. [The following is from a

letter by Mr. Fisher that was published in Engineering News, Feb. 7, 1901, further explaining the method.]

Referring to Fig. 3, prolong that portion of the balancing line which passes through Stas. 230 and 240 to the point P, its intersection with the horizontal line through Sta. 235; the lines of haul are drawn from this point to each point of flexture of the dotted and solid curves. The limit of haul is fixed by making the horizontal distance between the upper intersection 500 ft.

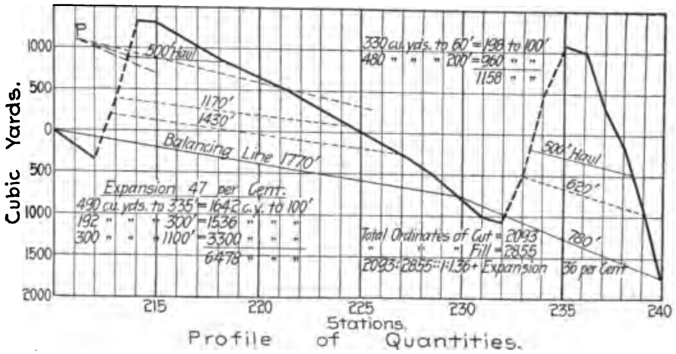



FIG. 3.

The swelling or shrinking of the material is shown by the relation between the extreme ordinates of the solid and dotted curves, as shown in Fig. 3. The balancing line is nearly always more or less inclined. It is horizontal only when the volumes of the adjacent cut and fill are equal to each other. The point P will not usually come within the limits of the drawing, and it is only in rare instances of great expansion or contraction of material that it is needed in practice. The inclination of the balancing line is generally so slight that the lines of haul can be drawn parallel to it or a trifle divergent.

## APPENDIX C.

### A Small "Home-Made" Dipper Dredge or Steam Shovel.*

There are many places where it is very difficult and expensive to take a dredge or steam shovel of moderate size, and there are many other places where the amount of excavation to be done is so small as to ordinarily make it unprofitable to attempt to use machinery. A simple and effective power excavator adopted for use either as a dredge or a land shovel was operated for some time by a member of our editorial staff, and the details of the parts are illustrated herewith.

While, as shown in Fig. 1, the excavating machinery may be mounted upon scows so as to form a dredge, it may also be mounted on trucks and used as a steam shovel of no mean efficiency considering the force of men employed.

Two scows, each of the dimensions shown in Fig. 2, are fastened together side by side as shown in Fig. 3. It is preferable to build two scows instead of one, for each can then be loaded upon a wagon, and one can be placed on top of the other on an ordinary flat car for railway transportation. These particular scows were made of rough 2-in. pine plank nailed to four roughly-made trusses as shown in Fig. 2, and calked. At first such scows leak somewhat, but a small hand pump will readily keep them bailed. Two spuds, shown in Figs. 1 and 8, support the front end of the scows during digging, the upper end of each spud being provided with teeth that fit into the rack on the A-frame shown in Fig. 3. The spuds are raised by a rope that runs back to the winch head of the engine. A single spud in the stern (Fig. 1) is handled in a similar manner by the engine. This engine is

*This dredge was described by the writer in Engineering News, May 14, 1903, from which issue the following is a reprint.

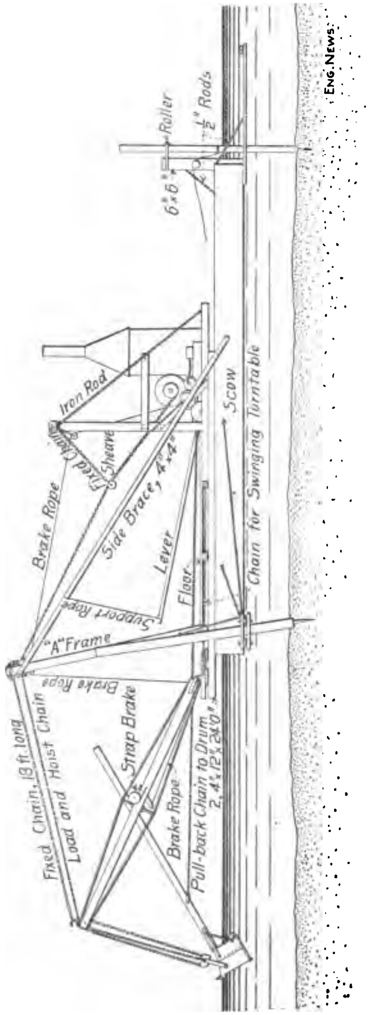



Fig. 1. Elevation of Dredge.

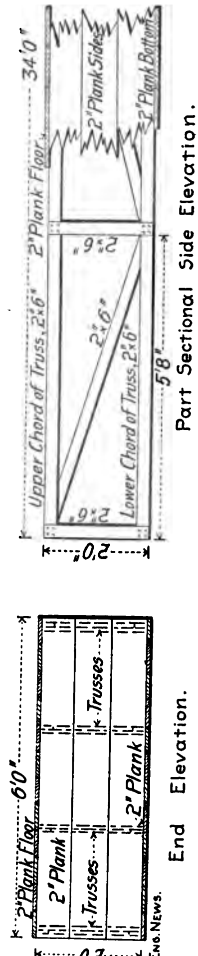



Fig. 2. End Elevation and Part Sectional Side Elevation of Scow.

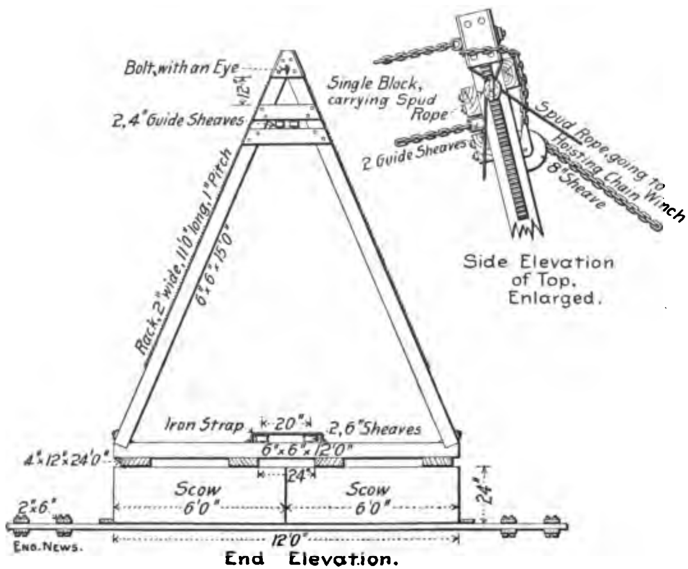



Fig. 3. End Elevation of A-Frame and Detail of Top.

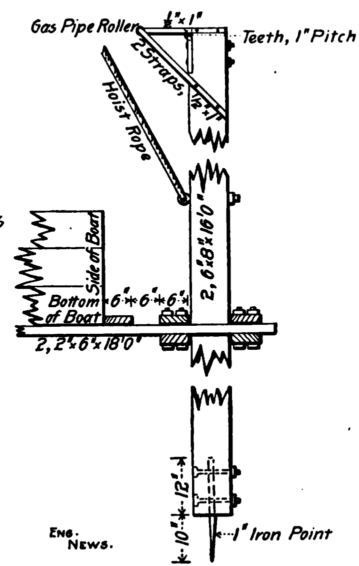



Fig. 8. End Elevation of One A-Frame Spud.

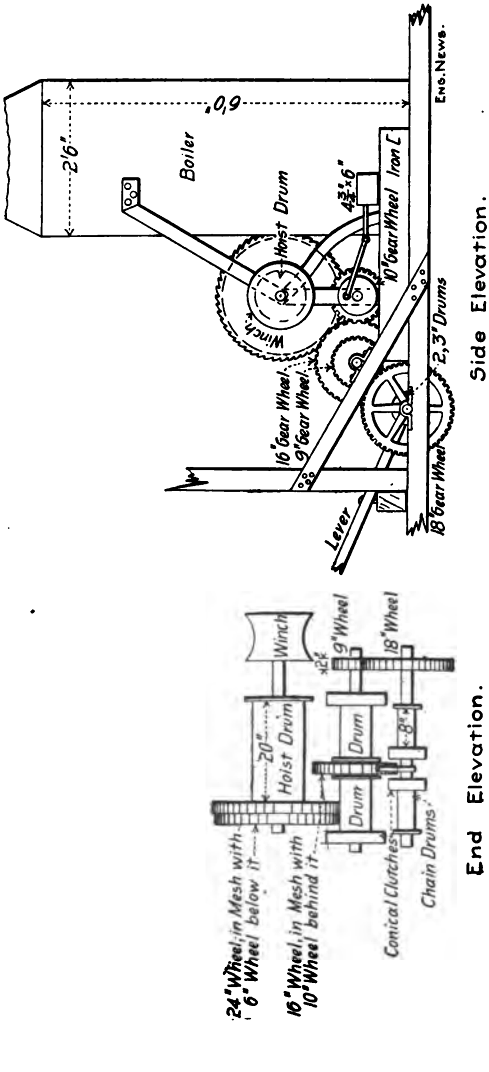



Fig. 9. Elevations of Engine.

an ordinary single drum (friction clutch) double-cylinder hoisting engine of 8 HP., this particular engine and boiler being made by The American Hoist & Derick Co., of St. Paul. The cylinders are $4\frac{3}{4} \times 6$ ins. The engine and boiler has a shipping weight of 3,500 lbs. The next size larger, 10 HP., would in many cases be worth its added cost.

A wooden framework was built, as shown in Fig. 9, and four additional drums and gear wheels were mounted on it by a local machinist. The two smallest of these drums (3 ins. diam. × 8 ins. long)

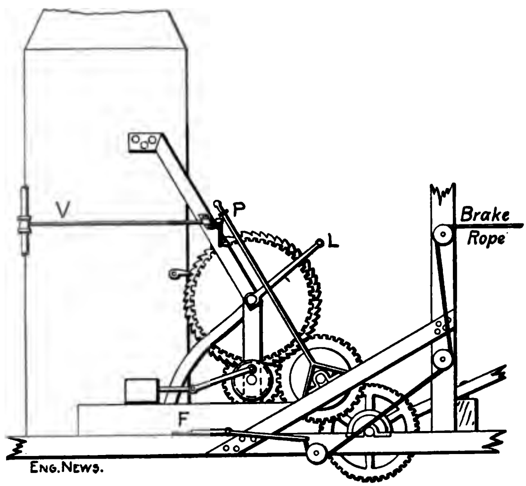



Fig. 10. Elevation Showing Levers Controlled by Engineman.

swing the dipper crane by means of chains. To effect a right or left swing as desired, each of these 3-in. drums has a conical friction clutch operated by a lever under the control of the dipperman at the front of the scow. The rest of the engine mechanism is under the control of one man—the engineman. Fig. 10 shows the levers under his control. L is the lever operating the friction clutch of the main or hoisting drum which is held in the

right hand; V is the lever with which the steam supply is controlled by the left hand; P is the lever that operates the clutch controlling the middle drum, around which is wound the pull back chain (Fig. 1) from the dipper (Fig. 2 shows two of these drums, marked "Drum," but only one was actually used), and this lever P is operated by the left shoulder of the engineman; F is a foot lever controlling the brake rope (Fig. 1) that restrains the dipper from sliding down while it is being pulled back to take a new scoop.

It will be seen that the engineman is called upon to do a good many things, and that his job is no "snap," but it has been found possible for a man to learn in a short time to thus handle the dipper with rapidity and with perfect success.

The details of the dipper itself and its arm or handle are well shown in Fig. 6, where it will be seen that its capacity level full is 9 cu. ft., or $^1/_3$ cu. yd. This dipper was made also at a local machine shop. Fig. 7 shows the boom, consisting of two yellow pine (3 × 8 ins.) sticks trussed with $\frac{3}{4}$-in rods above and below and on both sides. The dipper arm or handle, as shown in Fig. 1, passes between these two pine sticks of the boom, and the cog rack on the lower side of the dipper handle travel on 3-in. pinions mounted, as shown in Fig. 7, on the boom. These pinions are keyed to a shaft on the outer end of which is keyed a wheel controlled by a brake strap, so that the dipper arm can be held at any desired position. The lower end of this boom is fastened to the turntable shown in Fig. 5. The turntable is pivoted on the frame shown in Fig 4, and the two 4 × 12-in. × 24-ft. sticks, there shown, run back under the engine bed so that the weight of the engine and boiler counterbalances the weight of the dipper, boom, etc.

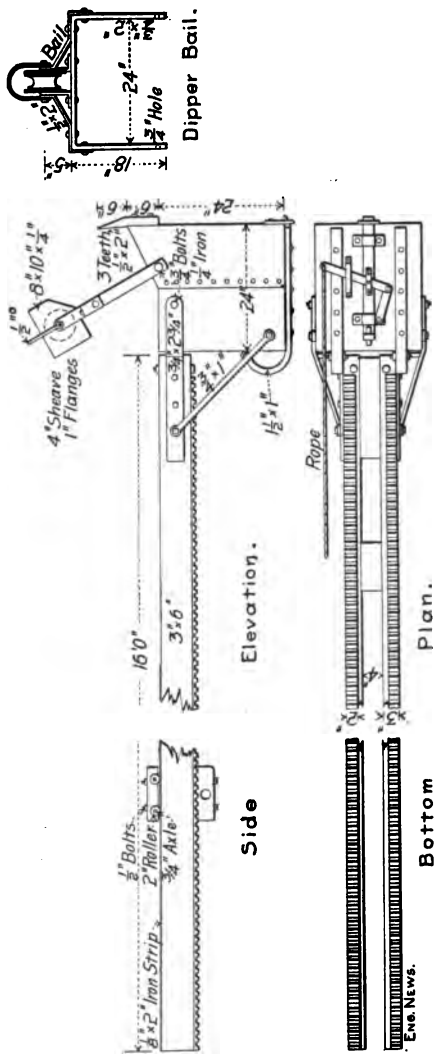



Fig. 6. Details of Dipper.

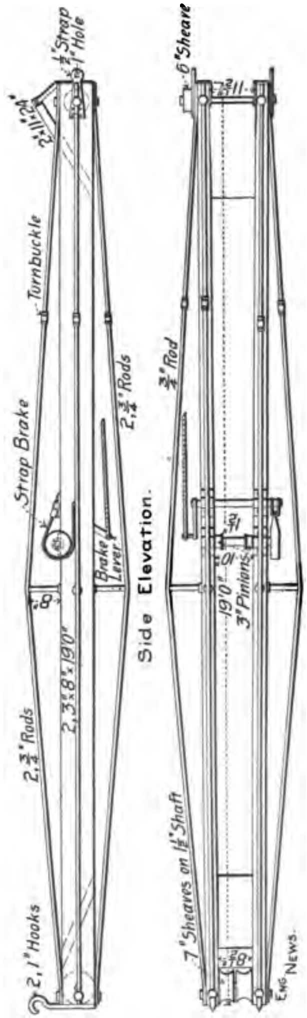



Fig. 7. Side Elevation and Plan of Boom.

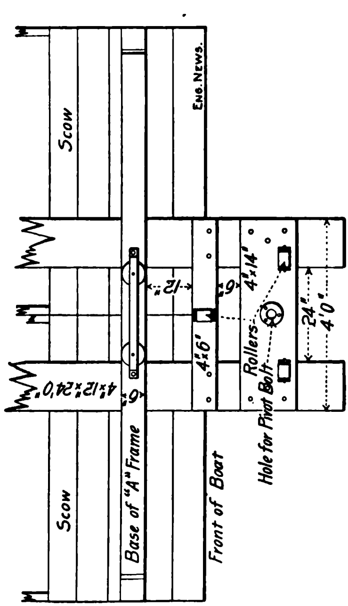



Fig. 4. Plan of Frame Supporting Turntable.

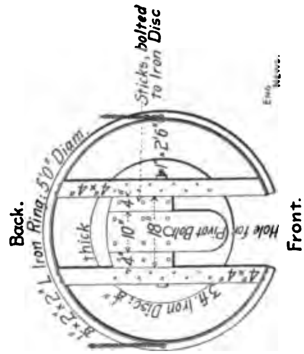



Fig. 5. Plan of Turntable.

## COST OF THE DREDGE.

| | | |
|---|---|---|
| 1 | Hoisting engine and boiler | $500 |
| 2 | Scows, 3,200 ft. B. M. | 100 |
| 10 | Sheaves, 6-in. | 20 |
| 120 | ft., 7-16-in. hoisting chain, 250 lbs. at 8 cts. | 20 |
| 160 | ft., $\frac{3}{4}$-in. iron, 250 lbs. at 4 cts. | 10 |
| 1 | Dipper, 400 lbs. at 10 cts. | 40 |
| 40 | ft. cast-iron rack, 200 lbs. at 10 cts. | 20 |
| 1 | Turntable plate and rim, 100 lbs. at 10 cts. | 10 |
| 100 | Bolts, $\frac{3}{4} \times 12$ ins., 200 lbs. at 5 cts. | 10 |
| 1,000 | ft. B. M. yellow pine | 30 |
| | Labor and sundries not included above. | 190 |
| | Total | $1,000 |

To show how cheaply the scows can be made, calked with oakum and pitched, we may add that a carpenter and a laborer were just 6 days in making two scows; 15 lbs. of oakum were used in calking. The following spring both scows were recalked (8 lbs. of oakum) by two men in 7 hours, then two men and a team were engaged 15 hours in skidding and launching the scows.

## COST OF DREDGING.

This dredge, including its scows, can be loaded on two flat cars (one would hold it) and it makes only four ordinary wagon loads over good earth roads. It takes 4 men $2\frac{1}{2}$ hours to load each scow onto a wagon and $\frac{1}{2}$-hour to unload. The crew is 3 men, consisting of an engineman, a dipperman and a fireman. After the scows are launched, this crew will place the engine and boiler on the scows in half a day, and will rig the dredge in two days more.

Records were kept of the work done by this bantam dredge under a variety of conditions. It

will dig a channel 18 ft. wide and 12 ft. deep with the dipper arm of the length shown, but for deeper digging a longer arm will be needed. By actual count 63 dipper loads were excavated in 48 mins., including 8 mins. for two forward moves of 5 ft. each, at which rate 25 cu. yds. of river gravel were excavated per hour. The average output for a 10-hour day was 175 cu. yds. in river gravel where occasionally a boulder would be dug up that completely filled the bucket. In hardpan this dredge averaged only 60 cu. yds. a day, alongside of a 1 cu. yd. dredge that did but little better, showing that, small as it is, the dredge will handle the toughest of material.

In pretty difficult material the dredge can be counted on for 150 cu. yds. per day of 10 hours, with a crew of three men, and a coal consumption of ¼-ton. Thus, at an expense of about $8 a day for labor and fuel, river gravel can be dredged for 5 or 6 cts. per cu. yd. with a small and simple machine whose first cost need not exceed $1,000.

Moreover, in the interim of dredging work, if there is any pile-driving or other hoisting engine work to do, the dredge can quickly be dismantled and its engine used for that purpose. Mounted on rollers or on wheels it has been used advantageously in dry excavation.

We may suggest in closing that in a new country, like Alaska, where labor is scarce and high-priced, an outfit of the kind described could be used in placer mining work on many a small claim that would not warrant a more expensive plant.

# INDEX

Jakl
750 nel

SND
G41
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